2. ANALYSIS

The risk analysis step involves assessing exposure to contaminants (characterization of exposure) and potential effects of exposure (characterization of effects). These activities are conducted interactively to ensure that the methods used to assess exposure and effects are compatible. Assessing exposure and effects is based on the ecological endpoints and conceptual models derived during the problem formulation presentation.

2.1 Exposure Calculations

Potential exposures for functional groups, including T/E and sensitive species were determined based on site-specific life history and feeding habits when possible. Quantification of group and individual exposures incorporated species-specific numerical exposure factors including body weight, ingestion rate (IR), and fraction of diet composed of vegetation or prey, and soil consumed from the affected area. Parameters used to model contaminant intakes by the functional groups and species (assessment endpoints) are presented in Table 9. These values were derived from a combination of parameters that produced the most conservative overall exposure for the group. The functional group parameters in Table 10 represent the most conservative combination of percent prey (PP), percent vegetation (PV), percent soil (PS), ED, IR, body weight, and home ranges from species within the functional group. The input parameters and exposure equations are documented in detail in the OU 10-04 RI/FS work plan (DOE-ID 1999).

Table 9. Parameter input values for EBSL calculations.

Functional Groups	PP	PV	PS	SUF	ED	IR (kg/day)	WI (L/day)	BW (kg)	PS Model Species[a]
Amphibians (A232)	9.41E-01	0.00E+00	5.90E-02	1.00E-00	1.00E-00	6.49E-05	0.00E+00	8.00E-03	Eastern painted turtle
Avian herbivores (AV121)	0.00E+00	9.90E-01	1.00E-02	1.00E-00	1.00E-00	3.50E-03	3.20E-03	1.29E-02	Estimated
Avian herbivores (AV122)	0.00E+00	9.07E-01	9.30E-02	1.00E-00	1.00E-00	1.46E-03	1.33E-03	3.50E-03	Wild turkey
Avian herbivores (AV132)	0.00E+00	8.20E-01	1.80E-01	1.00E-00	1.00E-00	1.07E-02	1.04E-02	7.46E-02	Western sandpiper
Avian herbivores (AV142)	0.00E+00	9.18E-01	8.20E-02	1.00E-00	1.00E-00	2.75E-02	2.73E-02	3.16E-01	Canada goose
Trumpeter swan	0.00E+00	9.18E-01	8.20E-02	1.00E-00	1.00E-00	2.75E-01	2.90E-02	1.09E+01	Canada goose
Avian herbivores (AV143)	0.00E+00	9.18E-01	8.20E-02	1.00E-00	1.00E-00	2.92E-02	2.92E-01	3.47E-01	Canada goose
Avian insectivores (AV210)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	2.90E-03	2.70E-03	1.00E-02	Estimated
Black tern	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	9.84E-03	9.48E-03	6.53E-02	Estimated
Avian insectivores (AV210A)	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	3.89E-03	3.48E-03	1.46E-02	Burrowing owl
Avian insectivores (AV221)	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	1.99E-03	2.05E-03	6.65E-03	Burrowing owl
Avian insectivores (AV222)	9.07E-01	0.00E+00	9.30E-02	1.00E-00	1.00E-00	3.07E-03	2.86E-03	1.09E-02	Wild turkey
Avian insectivores (AV222A)	9.07E-01	0.00E+00	9.30E-02	1.00E-00	1.00E-00	2.82E-03	2.70E-03	1.00E-02	Wild turkey
Avian insectivores (AV232)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	1.12E-03	1.01E-03	2.32E-02	Western sandpiper
Avian insectivores (AV233)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	4.78E-03	4.50E-03	2.15E-02	Western sandpiper

Table 9. (continued).

Functional Groups	PP	PV	PS	SUF	ED	IR (kg/day)	WI (L/day)	BW (kg)	PS Model Species[a]
White-faced ibis	8.90E-01	0.00E+00	1.10E-01	1.00E-00	1.00E-00	4.27E-02	4.29E-02	6.22E-01	Western sandpiper
Avian insectivores (AV241)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	6.41E-03	6.10E-03	3.38E-02	Western sandpiper
Avian insectivores (AV242)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	1.13E-02	1.10E-02	8.10E-02	Wood duck
Avian carnivores (AV310)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.61E-02	1.57E-02	1.39E-01	Wood duck
Northern goshawk	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	6.00E-02	6.10E-02	1.05E-00	Estimated
Peregrine falcon	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	4.96E-02	5.00E-02	7.82E-01	Estimated
Avian carnivores (AV322)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	7.44E-03	7.11E-03	4.25E-02	Estimated
Bald eagle	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.60E-01	1.67E-01	4.74E-00	Estimated
Ferruginous hawk	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	6.19E-02	6.29E-02	1.10E-00	Estimated
Loggerhead shrike	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	7.44E-03	7.11E-03	4.25E-02	Estimated
Avian carnivores (AV322A)	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	1.73E-02	1.69E-02	1.55E-01	Burrowing owl
Burrowing owl	9.70E-01	0.00E+00	3.00E-02	1.00E-00	1.00E-00	1.73E-02	1.69E-02	1.55E-01	Burrowing owl
Avian carnivores (AV333)	8.20E-01	0.00E+00	1.80E-01	1.00E-00	1.00E-00	1.84E-02	1.81E-02	1.71E-01	Western sandpiper
Avian carnivores (AV342)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	4.64E-02	4.67E-02	7.06E-01	Not modeled
Avian omnivores (AV422)	6.27E-01	2.80E-01	9.30E-02	1.00E-00	1.00E-00	1.13E-02	1.09E-02	8.02E-02	Wild turkey
Avian omnivores (AV432)	5.70E-01	2.50E-01	1.80E-01	1.00E-00	1.00E-00	2.75E-02	2.73E-02	3.16E-01	Western sandpiper
Avian omnivores (AV433)	5.70E-01	2.50E-01	1.80E-01	1.00E-00	1.00E-00	5.33E-02	5.39E-02	8.74E-01	Western sandpiper

Table 9. (continued).

Functional Groups	PP	PV	PS	SUF	ED	IR (kg/day)	WI (L/day)	BW (kg)	PS Model Species[a]
Avian omnivores (AV442)	6.20E-01	2.70E-01	1.10E-01	1.00E-00	1.00E-00	4.41E-02	4.44E-02	6.54E-01	Wood duck
Mammalian herbivores (M121)	0.00E+00	9.80E-01	2.00E-02	1.00E-00	1.00E-00	3.14E-01	4.82E-01	5.80E-00	Mule deer
Mammalian herbivores (M122)	0.00E+00	9.37E-01	6.30E-02	1.00E-00	1.00E-00	3.30E-03	1.71E-03	1.10E-02	Black-tailed jackrabbit[b]
Mammalian herbivores (M122A)	0.00E+00	9.23E-01	7.70E-02	1.00E-00	1.00E-00	4.27E-03	2.35E-03	1.57E-02	Black-tailed prairie dog
Pygmy rabbit	0.00E+00	9.80E-01	2.00E-02	1.00E-00	1.00E-00	4.53E-02	4.38E-02	4.04E-01	Black-tailed prairie dog
Mammalian herbivores (M123)	0.00E+00	9.23E-01	7.70E-02	1.00E-00	1.00E-00	1.51E-02	1.12E-02	8.89E-02	Black-tailed prairie dog
Mammalian insectivores (M210)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.43E-03	1.43E-03	9.03E-03	Beetle specialist
Mammalian insectivores (M210A)	9.80E-01	0.00E+00	2.00E-02	1.00E-00	1.00E-00	1.43E-03	7.88E-04	4.65E-03	Beetle specialist
Townsend's western big-eared bat	9.90E-01	0.00E+00	1.00E-02	1.00E-00	1.00E-00	2.37E-03	1.71E-03	1.10E-02	Moth specialist
Small-footed myotis	9.90E-01	0.00E+00	1.00E-02	1.00E-00	1.00E-00	1.44E-03	7.94E-04	4.69E-03	Moth specialist
Long-eared myotis	9.90E-01	0.00E+00	1.00E-02	1.00E-00	1.00E-00	1.77E-03	1.09E-03	6.65E-03	Beetle specialist
Mammalian insectivores (M222)	9.76E-01	0.00E+00	2.40E-02	1.00E-00	1.00E-00	1.66E-03	9.91E-04	6.00E-03	Meadow vole
Mammalian carnivores (M322)	9.23E-01	0.00E+00	7.70E-02	1.00E-00	1.00E-00	1.66E-02	2.09E-02	1.78E-01	Black-tailed prairie dog
Mammalian omnivores (M422)	8.06E-01	1.00E-01	9.40E-02	1.00E-00	1.00E-00	3.06E-03	2.53E-03	1.70E-02	Raccoon
Mammalian omnivores (M422A)	8.06E-01	1.00E-01	9.40E-02	1.00E-00	1.00E-00	2.60E-01	4.25E-01	5.05E-00	Fox

Table 9. (continued).

Functional Groups	PP	PV	PS	SUF	ED	IR (kg/day)	WI (L/day)	BW (kg)	PS Model Species[a]
Reptilian insectivores (R222)	9.76E-01	0.00E+00	2.40E-02	1.00E-00	1.00E-00	5.60E-05	0.00E+00	6.61E-03	Meadow vole
Sagebrush lizard	9.76E-01	0.00E+00	2.40E-02	1.00E-00	1.00E-00	5.60E-05	0.00E+00	6.61E-03	Meadow vole
Reptilian carnivores (R322)	9.52E-01	0.00E+00	4.80E-02	1.00E-00	1.00E-00	6.80E-03	0.00E+00	1.50E-02	Fox plus 2%
Plants	0.00E+00	0.00E+00	1.00E-00	1.00E-00	1.00E-00	—	—	—	

a. From Beyer, Conner, and Gerould (1994) unless otherwise noted.

b. Arthur and Gates (1988).

2.1.1 Exposure Modeling

The exposure equation used to calculate average daily soil intake is used to calculate the dose to functional groups and T/E species. For example, dose (intake) in mg/kg body weight-day can be estimated using the following equation, as adapted from EPA's *Wildlife Exposure Factors Handbook* (EPA 1993):

$$EE_{total} = EE_{soil/food} + EE_{water} \tag{1}$$

where

EE_{total}	=	total estimated intake from ingestion of soil, food, and water (mg/kg bodyweight-day)
$EE_{soil/food}$	=	estimated intake from ingestion of food and soil (mg/kg bodyweight-day)
EE_{water}	=	estimated intake from ingestion of water (mg/kg bodyweight-day).

$$EE_{\mathrm{soil/food}} = \frac{[(PP \times CP) + (PV \times CV) + (PS \times CS)] \times IR \times ED \times SUF}{BW} \tag{2}$$

where

$EE_{soil/food}$	=	estimated exposure from all complete exposure pathways (mg/kg body weight-day)
PP	=	percentage of diet represented by prey ingested (unitless)
CP	=	concentration of contaminant in prey item ingested (mg/kg)
PV	=	percentage of diet represented by vegetation ingested (unitless)
CV	=	concentration of contaminant in vegetation ingested (mg/kg)
PS	=	percentage of diet represented by soil ingested (unitless)
CS	=	concentration of contaminant in soil ingested (mg/kg)
IR	=	ingestion rate (kg/day), food intake rate (g/day) divided by 1,000 g/kg
ED	=	exposure duration (fraction of year spent in the affected area) (unitless)
BW	=	receptor-specific body weight (kg)
SUF	=	site usage factor (site area divided by home range; cannot exceed 1) (unitless).

The concentration of contaminant in prey can be estimated using the equation (VanHorn, Hampton, and Morris 1995):

$$CP = CS \times BAF \tag{3}$$

where

CP = concentration in prey item ingested (mg/kg)

CS = concentration of contaminant in soil (mg/kg)

BAF = contaminant-specific bioaccumulation factor (unitless).

The concentration of contaminant in vegetation (CV) can be estimated using the equation (VanHorn, Hampton, and Morris 1995):

$$CV = CS \times PUF \tag{4}$$

where

CV = concentration of contaminant in vegetation (mg/kg)

CS = concentration of contaminant in soil (mg/kg)

PUF = contaminant-specific plant uptake factor (unitless).

Contaminant-specific PUFs (from Baes et al. 1984 and other literature sources) and concentration factors (CFs) for calculating EBSLs for metals are presented in the OU 10-04 work plan (DOE-ID 1999). Concentration factors for metals were developed as discussed in the OU 10-04 work plan (DOE-ID 1999). The log of PUF and CFs for organics is estimated using 1.588-0.578 log K_{ow}, and -7.735 + 1.033 log K_{ow}, respectively (Travis and Arms 1988). Log partitioning coefficients (K_{ow}) were taken from the *Groundwater Chemicals Desk Reference* (Montgomery and Welkom 1990).

The exposure equation for exposure of dose in mg/kg body weight-day from surface water ingestion is as follows:

$$EE_{water} = CW * WI \tag{5}$$

where

EE_{water} = estimated intake from ingestion of surface water (mg/kg bodyweight-day)

CW = contaminant concentration in water (mg/L)

WI = water ingestion rate (L/kg bodyweight-day).

Where water ingestion rate is calculated as discussed in Section 2.3.3. Due to the complexity of water ingestion by reptiles, no general reptilian water ingestion equation is available. It is assumed here that desert reptiles, such as those found at the INEEL, get their water solely from prey.

2.1.2 EBSL Calculations

As discussed in detail in Appendix D of the OU 10-04 Work Plan (DOE-ID 1999), the EBSLs for contaminates of concern are useful for quickly screening soil contaminated sites for CERCLA work at the INEEL. The similarity in receptors across the facility makes it possible to develop INEEL-wide screening levels. EBSLs are defined as concentrations of COPCs in soil (or other media) that are not expected to produce adverse effects to selected ecological receptors under chronic exposure conditions. Water ingestion is not included. EBSLs are calculated by inverting the exposure equation. The exposure model estimates the potential intake. In the risk assessment process these intake values are compared to TRVs to evaluate potential effects to receptors. These equations can be manipulated to allow the calculation of a contaminant concentration in a medium that would not be potentially harmful to the receptors with chronic exposure.

To calculate EBSLs for screening against nonradiological soil contamination concentrations, the target hazard quotient (THQ) will be determined. This is defined as a quantitative method for evaluating potential adverse impacts to exposed populations.

$$THQ = \frac{EE_{\mathrm{soil}}}{TRV} \tag{6}$$

where

THQ = target hazard quotient (unitless), established at 1.0 for nonradionuclide contaminate exposure

EE_{soil} = estimated exposure from soil (mg/kg body weight-day)

TRV = contaminant-specific toxicity reference value (mg/kg-day).

Thus, solving for the concentration of the nonradionuclide contaminant in the soil (CS) and assuming that when THQ equals 1 that EE_{soil} = TRV. The EBSL for contaminant in the soil is calculated using Equation 7.

$$NR-EBSL_{soil} = \frac{TRV \times BW}{[(PP \times BAF) + (PV \times PUF) + (PS)] \times IR \times ED \times SUF} \tag{7}$$

where

$NR{-}EBSL_{soil}$ = INEEL-specific ecological based screening level for non-radionuclide contaminants in soil (mg/kg). (8)

Exposure parameters including dietary composition (percent soil [PS], percent prey [PP], and percent vegetation [PV]), home range, temporal and spatial habitat use data (site use factor [SUF] and ED), soil IR, food IR, body weight (BW), and uptake factors (bioaccumulation factors [BAFs] and plant uptake factors [PUFs]) are input to calculate the EBSL. The input values for calculating EBSLs for each functional group/contaminant combination assume that members of the functional groups are exposed to stressors to the maximum extent, perhaps beyond what is actually expected. For example, it is assumed that a raptor captures 100% of its prey from a contaminated site, and that all the prey are exposed to maximum contaminant concentrations at the site. This is similar to the human risk assessment concept of the "maximally exposed individual," a hypothetical individual who is assumed to live and grow his own food at a location of maximum exposure to a stressor. Each parameter is discussed in more detail in the OU 10-04 Work Plan (DOE-ID 1999). The defaults used in the calculation of EBSLs are presented in Table 10.

Table 10. Parameter defaults and assumptions for EBSL calculations.

Parameter	EBSL Soil/Sediment Calculations
PV	Herbivores—100 minus PS Insectivores—0 Carnivores—0 Omnivores—PV from literature minus PS/2
PP	Herbivores—0 Insectivores—100 minus PS Carnivores—100 minus PS Omnivores—PP from literature minus PS/2
PS	The highest value (i.e., greatest exposure) was selected from species within functional group. Individual species evaluated using values as presented. (see Table 9)
IR	Allometric equations from Nagy (1987). The largest IR/BW ratio was used from the species within a functional group.
WI	Allometric equations from the *Wildlife Exposure Factors Handbook* (EPA 1993) were used.
BW	The smallest BW/IR ratio was selected from species within each functional group.
ED	Defaulted to 1
SUF	Defaulted to 1

2.2 Development of EBSLs for Radionuclide Contaminants

The method used for relating the amount of radiation to specific biological effects is the radiation dose rate, which is a measure of the amount of radiation energy that is dissipated in a given volume of living tissue. Radionuclide exposure can occur from both external contact and internal ingestion. These issues will be presented separately.

2.2.1 Internal Radiation Dose Rate from Soil Exposure

Internal radiation dose rate estimates are calculated by assuming that the steady-state whole body concentration is equivalent to the steady-state concentration of radionuclides in reproductive organs using Equation (9). This is as presented in IAEA (1992).

$$DR_{internal} = \frac{TC \times ED \times SUF \times ADE \times FA \times 3200\ dis/day\text{ - }pCi}{6.24 \times 10^9\ MeV/g\text{ - }Gy} \quad (9)$$

where

$DR_{internal}$ = internal radiation dose rate estimate (Gy/day)

TC = tissue radionuclide concentration (pCi/g)

ED = exposure duration (fraction of year spent in affected area) (unitless)

SUF = site use factor (affected area/receptor home range [unitless]; defaulted to 1.0 for EBSL calculation)

ADE = average decay energy per disintegration (MeV/dis)

FA = fraction of decay energy absorbed (unitless).

Since tissue levels of radionuclides are derived by multiplying the concentration of radionuclide in soil by a radionuclide-specific CF for all terrestrial animals or terrestrial plants, the above equation can be rewritten as Equation (10).

$$DR_{internal} = \frac{CS \times CF \times ED \times ADE \times FA \times 3200\ dis/day\text{ - }pCi}{6.24x10^9\ MeV/g\text{ - }Gy} \quad (10)$$

where

CS = concentration of contaminant in soil ingested (pCi/g)

CF = concentration factor (unitless).

Solving for the concentration of contaminant in soil (CS) and redefining this concentration as an EBSL, the EBSL for internal consumption of radiological contaminants from contaminated soil media is estimated using Equation (11).

$$EBSL_{internal} = \frac{TRV \times 6.24 \times 10^{9}\ MeV/g\text{ - }Gy}{CF \times ED \times ADE \times FA \times 3200\ dis/day\text{ - }pCi} \tag{11}$$

where

$EBSL_{internal}$ = internal ecological based screening level for radionuclides in soil (pCi/g)

TRV = toxicity reference value (Gy/day).

Assumptions used in the calculation of the ADE values were for radiations whose energy would be deposited in small tissue volume (ß,a), the FA was set equal to 1. For gamma radiation, the FA was conservatively set equal to 0.3 (30%). This assumption was assumed to be conservative (IAEA 1992). Only radiations with an intensity of 1% or greater were considered, and Auger and conversion electrons were not considered. The ADE values were calculated using Equation (12) (Kocher 1981):

$$ADE = \sum_{i=1}^{n} Y_i\, E_i \tag{12}$$

where

ADE = average decay energy per disintegration (MeV/dis)

Y_i = yield or intensity

E_i = energy of radiation, for ß = average energy.

CFs for radionuclides are discussed in VanHorn, Hampton, and Morris (1995). For EBSL development the CF values for animals are assumed to be 1 for contaminants and receptors unless reported values for CF are larger (in this case the larger CF value is used).

2.2.2 External Radiation

External dose rate EBSLs are derived using formulas outlined in Shleien (1992). Dose rate to tissue in an infinite medium uniformly contaminated by a gamma emitter is calculated by Equation (13).

$$DR_{external} = \frac{2.12 \times ADE \times C}{\rho} \tag{13}$$

where

$DR_{external}$ = external dose rate to tissue (rads/hr)

ADE = average gamma decay energy per disintegration (MeV/dis)

C = concentration of contaminant (μCi/cm^3)

ρ = density of the medium (g/cm^3).

Solving the equation for the concentration in soil assuming an acceptable dose to animals is 1 mGy/day (0.1 rad/day, which is equal to 4.12E-03 rad/hr) (IAEA 1992) and redefining this concentration as an EBSL, the EBSL for external dose from radiological contaminants in soil is estimated using Equation (14).

$$\mathrm{EBSL}_{\mathrm{external}} = \frac{\mathrm{DR}_{\mathrm{external}} \times 10^{6}\ \mathrm{pCi}/\mu\mathrm{Ci}}{2.12 \times \mathrm{ADE}} \tag{14}$$

where

$EBSL_{external}$ = ecologically based screening level for external exposure to radionuclides in soil (pCi/g)

$DR_{external}$ = external dose rate to tissue (rads/hr)

ADE = average gamma decay energy per disintegration (MeV/dis).

This equation conservatively estimates the dose to burrowing terrestrial functional groups (AV210A, AV222A, M122A, M210A, and M422). This equation also conservatively reflects that these functional groups spend 100% of their time with external exposure. For the nonburrowing functional groups, it is conservatively assumed that they are exposed to 50% (hemisphere) of radiation.

The dose rate for use in the external EBSL calculation is 4.12E-03 rads/hr as discussed above. Contaminant-specific average decay energies and FA values for the radionuclides of concern are presented in VanHorn, Hampton, and Morris (1995).

2.3 Parameter Input Values

EBSLs were calculated using the species-specific input values (PV, PP, PS, IR, WI, BW, ED, SUF) compiled from the literature. Exposures for each functional group or species incorporate best estimates to reflect species-specific life history and feeding habits. These values have been explicitly developed to reflect INEEL contaminant issues. Individual parameter values and literature sources are discussed in the following subsections.

2.3.1 Diet (PV, PP, PS)

Group and individual species diets are represented in the EBSL equations by the sum of three parameters (percent vegetation [PV], percent prey [PP], and percent soil [PS]), constrained to equal 100%. For herbivores, PV is represented by 1 – PS (where PP = 0). No distinction was made between the types of vegetation consumed. Although some primarily herbivorous species may consume a small percent of its diet as insect prey, this was considered in the trophic assignment as part of the functional grouping criteria (VanHorn, Hampton, and Morris 1995).

For carnivores, PP is represented by 1 – PS (where PV = 0). Values for the fraction of overall diet represented by prey were taken from species-specific or representative species diets as reported in the literature.

Dietary composition for omnivores is represented by (PV-PS/2) + (PP-PS/2) + PS = 1 unless PP or PV are 10% or less, in which case, PS was subtracted from the greater of the two. Dietary profiles for functional groups were based on diets for representative species developed from studies conducted at the INEEL and other regional locations. Since most dietary studies report only in terms of prey or vegetation material, the dietary fraction comprised of soil was evenly subtracted from prey and vegetation fractions of the diet to account for inclusion of ingested soil without exceeding 1. The number of individual species comprising prey was not considered. The contribution of prey items to overall diet was based on relative biomass rather than the most numerous individual components. Dietary composition for functional groups is represented by the species having the largest PS within that group.

As shown in Table 9, the values for PS for each functional group were taken primarily from soil ingestion data presented by Beyer, Conner, and Gerould (1994). Species for which values were presented in Beyer, Conner, and Gerould (1994) are limited, so soil ingestion values were assigned using professional judgement to match dietary habits with species most similar to INEEL species represented by functional groups. This selection process is documented in Appendix D2 of the OU 10-04 Work Plan (DOE-ID 1999).

2.3.2 Body Weight (BW)

Body weights (BWs) for mammals, amphibians, and reptiles were extracted from numerous local and regional studies. Body weights for birds were taken primarily from Dunning (1993) unless local or regional values were available. Values were chosen in order of preference for study locale: (1) INEEL, (2) Idaho, (3) Regional (sagebrush steppe in Washington, Oregon, Wyoming, Nevada and northern Utah), and (4) U.S.-wide. Where no distinction in sex was reported, mean adult weights were used. In cases where only separate means for male and female were reported, the average of the two was calculated. In cases where only a range in weights could be found, a median value was used. The basis of the body weight selection used for the functional groups is presented in the OU 10-04 work plan (DOE-ID 1999). Functional group weight represents the smallest individual species body weight in the group.

2.3.3 Food and Water Ingestion Rates (IR, WI)

Food/prey IRs for most INEEL species were calculated using allometric equations given in Nagy (1987). Food intake rates (grams dry weight per day) for passerine birds, nonpasserine birds, rodents, herbivores, all other mammals, and insectivorous reptiles were estimated using the following allometric equations (Nagy 1987).

$$\text{Food intake rate} = 0.398\ BW^{0.850}\ \text{(passerines)} \tag{15}$$

$$\text{Food intake rate} = 1.110\ BW^{0.445}\ \text{(desert bird)} \tag{16}$$

$$\text{Food intake rate} = 0.648\ BW^{0.651}\ \text{(all birds)} \tag{17}$$

$$\text{Food intake rate} = 0.583\ BW^{0.585}\ \text{(rodents)} \tag{18}$$

$$\text{Food intake rate} = 0.577\ BW^{0.727}\ \text{(mammalian herbivores)} \tag{19}$$

$$\text{Food intake rate} = 0.235\ BW^{0.822}\ \text{(all other mammals)} \tag{20}$$

$$\text{Food intake rate} = 0.15\ BW^{0.874}\ \text{(desert mammals)} \tag{21}$$

$$\text{Food intake rate} = 0.013\ BW^{0.773}\ \text{(reptile insectivores)} \tag{22}$$

where BW = body weight in grams.

An equation for IRs for carnivorous reptiles (R322) was constructed using data reported by Diller and Johnson (1988):

$$Food\ intake\ rate = 0.01\ BW^{1.6}\ (reptile\ carnivores) \tag{23}$$

where BW = body weight in kilograms.

These equations were applied to estimate the IR (g dry weight/day) as a function of body weight. The application of individual equations for species and groups varies according to taxonomic Class and/or Order and in some cases, habitat (e.g., aquatic species). In cases where more than one of Nagy's (1987) equations could be applied to a functional group, such as all mammals or desert rodents, the larger of the two rates was applied. For functional groups in which mixed species occur, intake rates were calculated using the most representative or generic equation returning the largest IR. Food IRs for functional groups evaluated for the ICDF Complex are presented in Table 10.

Water IRs were calculated for functional groups and individual species using the dry diet allometric equations for birds and mammals (EPA 1993). Reptiles and amphibians were assumed to attain water through absorption and metabolic processes. Although other species (some birds and small mammals) meet water needs through metabolic and dietary means, these species were assumed to ingest water for drinking based on the equations. Allometric equations used in calculating water IRs for individual species and functional groups are presented below.

Water ingestion for individual species was found from the following equations (EPA 1993):

$$WI = 0.059\ BW^{0.67}\ (for\ all\ birds) \tag{24}$$

$$WI = 0.099\ BW^{0.90}\ (for\ all\ mammals). \tag{25}$$

Water IRs for functional groups evaluated for the ICDF Complex are presented in Table 10.

2.3.4 Exposure Duration (ED)

Exposure duration (ED) represents the fraction of year an animal spends in the affected area. Because EBSL screening values were designed to be conservative, ED was assumed to be 1 for all receptors, assuming 100% of their time is spent in the assessment area.

2.3.5 Site Use Factor (SUF)

The site use factor (SUF) represents the proportion of a species' home range that overlaps the area of contamination. An SUF of 1 indicates that the home range is less than or equal to the area of contaminant exposure. For EBSL screening, the SUF was assumed to be 1 (100% use occurs in the area of contamination) for all groups and species (see VanHorn, Hampton, and Morris 1995).

2.3.6 Bioaccumulation Factors (BAF, PUF)

The uptake of contaminants in the terrestrial food chain is important for realistically calculating exposure to contamination. These contaminant-specific factors are referred to in the literature as uptake factors or PUFs for plants and food-chain transfer coefficients or factors for wildlife. The PUF is the plant tissue concentration of the contaminant divided by the soil or sediment concentration. The food-chain transfer factor is the animal tissue concentration of a contaminant divided by the concentration in its food. To estimate the tissue levels of contaminants in prey, the PUF was multiplied by the transfer factors to derive a "bioaccumulation factor" (BAF), which is the concentration of a contaminant in the tissues of an animal divided by the soil or sediment concentration. The BAF accounts for all ingestion exposure routes. For example, the BAF for a herbivorous small mammal is the PUF times the plant-to-herbivore transfer coefficient. Multiplying the small mammal BAF times the concentration of a contaminant in soil provides an estimate of the tissue levels of the contaminant in small mammals. This tissue level may then be used to estimate exposure for the carnivore/omnivore functional groups that are predators of small mammals.

BAFs and PUFs developed for the INEEL and used in the calculation of screening level values and EBSLs were defaulted to 1.0 or greater.

2.4 Uncertainty Analysis

2.4.1 Uncertainty Associated with Functional Groups

The selection of receptor parameters used is designed to ensure that each of the members of the functional groups is conservatively represented. Since all members of a functional group are considered similar, it is reasonable to assume that all members of a group will be equally exposed to site-related contaminants. Quantification of dose for each functional group is expected to provide sufficient data to assess the general condition of the ecosystem and to be adequately protective of the majority of species potentially inhabiting the assessment area. In addition, sensitive species are included on the list of receptors for which dose is calculated. Hence, uncertainty associated with the selection of receptor parameters is expected to minimally influence dose estimates.

2.4.2 Uncertainty Associated with the Ingestion Rate

Terrestrial receptor intake (ingestion) rates are based upon data in the scientific literature, when available. Food IRs are mostly calculated by use of allometric equations reported in Nagy (1987). Uncertainties associated with the use of allometric equations could result in either an overestimation or underestimation of the true dose rate, since actual IRs are known for few species.

2.4.3 Uncertainty Associated with the Receptor Site Usage

The calculation of dose incorporated the probability that the receptors may use or inhabit each site. The SUF is defined as the affected area (ha) divided by the home range (ha) of the receptor. If a given receptor's home range is larger than the affected area, then it is reasonable to assume that the receptor may not spend 100% of its life within the site area. Incorporation of the SUF adjusts the dose to account for the estimated time the receptor spends on the site. The less time spent on the site, the lower the dose. However, most home ranges are estimated from available literature values and allometric equations. Home range and usage of areas also vary from season to season as well as year to year (depending on the species of interest), and are difficult to measure (this uncertainty could result in either an overestimation or underestimation of the true dose rates).

2.4.4 Uncertainty Associated with the PUFs and BAFs

There is a great deal of uncertainty associated with the BAFs used to calculate dose. Very few BAFs are available in the scientific literature, since they must be both contaminant- and receptor-specific. In the absence of specific BAFs, a value of 1 was assumed. This assumption could over- or underestimate the true dose from the contaminant, and the magnitude of error cannot be quantified. Travis and Arms (1988) and Baes et al. (1984) report BAFs for contaminants to beef and milk; all of these are less than 1 for the contaminants in the assessment area. If the terrestrial receptors of concern accumulate metals and PCBs in a similar way and to a comparable degree as beef and dairy cattle, the use of a BAF of 1 for all contaminants and receptors would overestimate the dose. On the other hand, if the terrestrial receptors of concern for WAG 3 accumulate metals and PCBs to a much larger degree than beef and dairy cattle, the assumption of BAFs equal to 1 could underestimate the true dose from the COPCs.

2.4.5 Uncertainty Associated with Soil Ingestion

The exposure assessment incorporates percentage of soil ingested by each representative of the functional groups. Although food IRs have the greatest effect on intake estimates, soil IRs could also influence intake rates and, therefore, dose estimates. The EPA *Wildlife Exposure Factors Handbook* (EPA 1993) and Beyer, Conner, and Gerould (1994) were used to assign soil ingestion parameters to four of the twelve functional groups, and Arthur and Gates (1988), as noted in Table 9, was used to assign percent soil ingested by two common species (estimating the percent soil ingested may overestimate or underestimate the dose since the effect of the estimated values on the overall dose outcome is dependent on the concentration of contaminant in the media of concern).

2.4.6 Uncertainty Associated with Toxicity Data

The derivation of final TRVs for the various receptors and contaminants typically includes uncertainty factors (UFs) associated with extrapolation from laboratory studies and UFs incorporated to adjust toxicity from lethal doses to chronic doses. There are especially large uncertainties in the plant and soil invertebrate toxicity information since plants and soil organisms can adapt to a wide range of soil conditions. There are other sources of uncertainty that are not addressed using numerical uncertainty factors. For example, that laboratory studies used as a basis for generating TRVs may not accurately represent the complexities of potential exposure under field conditions. For example, the dosing of test animals by use of highly soluble salts in drinking water may over estimate exposures compared to the same salt administered in food. The chemical form present at the site may be in a less soluble form than that used in the laboratory study. In addition, some studies used to generate TRVs are not chronic in nature. It is difficult to interpret the potential for long-term ecological effects from acute or subchronic studies. Toxicological studies on which TRVs are based deal with a single chemical; effects of simultaneous exposure to multiple contaminants are not addressed.

TRVs are not available for a number of contaminants and receptors, and an EBSL cannot be calculated. When EBSLs or TRVs are not available it increases the possibility of underestimating risks.

Several of the COPCs and radiological COPCs were eliminated from consideration based on the lack of EBSL information. As is mentioned before, the contaminat concentrations are very conservatively modeled and the elimination of several of these COPCs is not considered to be significant. Risk may be underestimated but not to the point of being a major concern.

2.5 Ecological Effects Assessment

Ecological effects assessment consists of three elements:

- Selecting quantified critical exposure levels (QCELs)
- Developing adjustment factors (AFs)
- Developing TRVs.

The WAG 10 work plan (DOE-ID 1999) contains a general description of the procedures of ecological effects assessment and discussions of the each of the three elements as they apply to the development of TRVs for individual COPCs evaluated.

Information on the toxicological effects on mammalian receptors of the following contaminants was not located. Therefore, these contaminants could not be evaluated for potential risk.

1,1,2-Trichloroethane	Bi-211	Dysprosium
1,1-Dichloroethane	bis(2-Chloroethoxy)methane	Eicosane
1,1-Dichloroethene	bis(2-Chloroethyl)ether	Ethyl cyanide
1,2-Dichlorobenzene	bis(2-Chloroisopropyl)ether	Eu-150
1,2-Dichloroethene (total)	bis(2-Ethylhexyl)phthalate	Famphur
1,4-Dichlorobenzene	Bk-249	Heptadecane, 2,6,10,15-Tetra
2,4,5-Trichlorophenol	Bk-250	Hexachlorobenzene
2,4,6-Trichlorophenol	Butane,1,1,3,4-Tetrachloro-	Hexachlorobutadiene
2,4-Dichlorophenol	Calcium	Hexachlorocyclopentadiene
2,4-Dinitrophenol	Carbazole	Hexachloroethane
2-Chloronaphthalene	Carbon Disulfide	Ho-166m
2-Chlorophenol	Cd-113m	In-114
2-Hexanone	Cd-115m	In-114m
2-Methylphenol	Cf-249	In-115
2-Nitroaniline	Cf-250	Iron
2-Nitrophenol	Cf-251	Isobutyl alcohol
3,3-Dichlorobenzidine	Chloride	Isophorone
3-Methyl Butanal	Chlorobenzene	Isopropyl Alcohol/2-propanol
3-Nitroaniline	Chloroethane	Kepone
4,6-Dinitro-2-methylphenol	Chloromethane	Kr-81
4-Bromophenyl-phenylether	Cm-241	Manganese
4-Chloro-3-methylphenol	Cm-243	Mesityl oxide
4-Chlorophenyl-phenylether	Cm-245	Methyl Acetate
4-Methyl-2-Pentanone	Cm-246	Nb-92
4-Nitroaniline	Cm-247	Nb-95m
4-Nitrophenol	Cm-250	Nd-144
Acenaphthylene	Cs-135	Nitrate/Nitrite-N
Acrolein	Decane, 3,4-Dimethyl	Nitrite
Am-242m	Diacetone alcohol	N-Nitroso-di-n-propylamine
Am-246	Dibenz(a,h)anthracene	N-Nitrosodiphenylamine
Aramite	Dibenzofuran	Np-235
Benzidine	Dimethyl Disulfide	Np-236
Benzoic acid	Dimethylphthalate	Np-238

Np-240
Octane,2,3,7-Trimethyl
o-Toluenesulfonamide
Pa-234
Pb-209
Pb-211
Pd-107
Phenol,2,6-Bis(1,1-Dimethyl)
Phosphorus
Pm-146
Pm-148
Pm-148m
Po-211
Po-213
Po-215
Potassium
Pr-144m
p-Toluenesulfonamide
Pu-236
Pu-237
Pu-243
Pu-246
Ra-222
Ra-223
Rb-87
Rh-102
Rn-218
Rn-219
Sb-126
Sb-126m
Se-79
Sm-146
Sm-148
Sm-149
Sm-151
Sn-121m
Sn-123
Sn-126
Styrene
Sulfide
Tb-160
Tc-98
Te-123
Te-123m
Te-127
Te-127m
Te-129
Te-129m
Terbium
Th-226
Th-227
Tl-207
Tl-208
Tl-209
Tm-171
Undecane,4,6-Dimethyl-
Xe-127
Y-91
Ytterbium

Information on the toxicological effects on avian receptors of the following contaminants was not located. Therefore these contaminants could not be evaluated for potential risk.

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2,4-Trichlorobenzene
1,2-Dichlorobenzene
1,2-Dichloroethene (total)
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,4-Dioxane
2,4,5-Trichlorophenol
2,4,6-Trichlorophenol
2,4-Dichlorophenol
2,4-Dimethylphenol
2,4-Dinitrophenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
2-Butanone
2-Chloronaphthalene
2-Chlorophenol
2-Hexanone
2-Methylnaphthalene
2-Methylphenol
2-Nitroaniline
2-Nitrophenol
3,3-Dichlorobenzidine
3-Methyl Butanal
3-Nitroaniline
4,6-Dinitro-2-methylphenol
4-Bromophenyl-phenylether
4-Chloro-3-methylphenol
4-Chloroaniline

4-Chlorophenyl-phenylether
4-Methyl-2-Pentanone
4-Methylphenol
4-Nitroaniline
4-Nitrophenol
Acenaphthene
Acenaphthylene
Acetone
Acetonitrile
Acrolein
Acrylonitrile
Am-242m
Am-246
Anthracene
Aramite
Aroclor-1260
Be-10
Benzene
Benzidine
Benzo(a)anthracene
Benzo(a)pyrene
Benzo(b)fluoranthene
Benzo(g,h,i)perylene
Benzo(k)fluoranthene
Benzoic acid
Bi-210
Bi-211
bis(2-Chloroethoxy)methane
bis(2-Chloroethyl)ether
bis(2-Chloroisopropyl)ether
bis(2-Ethylhexyl)phthalate
Bk-249
Bk-250
Butane,1,1,3,4-Tetrachloro-
Butylbenzylphthalate
C-14
Calcium
Carbazole
Carbon Disulfide
Cd-113m
Cd-115m
Cf-249
Cf-250
Cf-251
Chloride
Chlorobenzene
Chloroethane
Chloromethane
Chrysene
Cm-241
Cm-243
Cm-245
Cm-246
Cm-247
Cm-250
Cs-135
Decane, 3,4-Dimethyl
Diacetone alcohol
Dibenz(a,h)anthracene
Dibenzofuran
Diethylphthalate
Dimethyl Disulfide
Dimethylphthalate
Di-n-butylphthalate
Di-n-octylphthalate
Dysprosium
Eicosane
Ethyl cyanide
Ethylbenzene
Eu-150
Famphur
Fluoranthene
Fluorene
Gd-152
H-3
Heptadecane, 2,6,10,15-Tetra
Hexachlorobenzene
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachloroethane
Ho-166m
In-114
In-114m
In-115
Indeno(1,2,3-cd)pyrene
Iron
Isobutyl alcohol
Isophorone
Isopropyl Alcohol/2-propanol
Kepone
Kr-81
Manganese
Mesityl oxide
Methyl Acetate
Methylene Chloride
Naphthalene
Nb-92
Nb-95m
Nd-144
Nitrate/Nitrite-N
Nitrite
Nitrobenzene
N-Nitroso-di-n-propylamine
N-Nitrosodiphenylamine
Np-235

Np-236
Np-238
Np-240
Octane,2,3,7-Trimethyl
o-Toluenesulfonamide
Pa-234
Pb-209
Pb-211
Pd-107
Pentachlorophenol
Phenanthrene
Phenol
Phenol,2,6-Bis(1,1-Dimethyl)
Phosphorus
Pm-146
Pm-147
Pm-148
Pm-148m
Po-210
Po-211
Po-212
Po-213
Po-214
Po-215
Po-216
Po-218
Potassium
Pr-144m
p-Toluenesulfonamide
Pu-236
Pu-237
Pu-241
Pu-243
Pu-246
Pyrene
Ra-222
Ra-223
Ra-228
Rb-87
Rh-102
Rn-218
Rn-219
Ru-106
Sb-126
Sb-126m
Se-79
Sm-146
Sm-147
Sm-148
Sm-149
Sm-151
Sn-121m
Sn-123
Sn-126
Sr-90
Strontium
Styrene
Sulfide
Tb-160
Tc-98
Te-123
Te-123m
Te-127
Te-127m
Te-129
Te-129m
Terbium
Tetrachloroethene
Th-226
Th-227
Tl-207
Tl-208
Tl-209
Tm-171
Toluene
Tributylphosphate
Trichloroethene
Undecane,4,6-Dimethyl-
Xe-127
Xylene (ortho)
Xylene (total)
Y-91
Ytterbium
Zirconium
Zr-93

3. RISK EVALUATION

Risk evaluation is the final step of the SLERA process. The risk evaluation determines whether there is any indication of risk from contaminants modeled at the ICDF Complex to INEEL functional groups, and subsequently T/E and sensitive species and discusses the uncertainty inherent in the assessment.

The risk assessment is focused on both the evaporation pond and landfill as is shown in Figures 5 and 6. Figure 5 presents the risk assessment approach used to evaluate the COPCs. This is primarily identifying those COPCs that are solely soil contaminant issues and those for which associated leachate concentration have been identified (see Tables 1–3). Those COPCs that are strictly identified as being restricted to the landfill are addressed as presented in Figure 7. Those COPCs that have both a soil and a water concentration will be evaluated through the hazard quotient process. The total hazard quotient or hazard index will be used to evaluate "cumulative" risk from multiple contaminants.

The evaluation of the radiological contaminants of potential concern is presented in Figure 6. There are only three radionuclides for which both soil and water concentrations are identified by EDF-ER-264 and EDF-ER-274. These are I-129, Tc-99, and U-238. These three radiological COPCs will be evaluated using the Biotic Dose Assessment Methodology as discussed below.

3.1 Screening of Contaminants of Potential Concern

Tables 11 through 14 compare modeled concentrations of contaminant in soil and water to EBSLs and Biotic Dose Assessment values (DOE-ID 2000) for the COPCs and radiological COPCs identified at the ICDF landfill and evaporation pond. Concentrations for soil at each level of screening and assessment were developed as presented in Figure 7. In Tables 11 through 14, a highlighted concentration value for a COPC indicates that the contaminant was brought forward in the assessment.

3.1.1 Initial Screening in Soil

The initial screening was based on the maximum contaminant masses presented in the Design Inventory (EDF-ER-264). The maximum mass of each COPC (totaled for all sites) was divided by the volume capacity of the ICDF landfill (389,000 m^3) to yield the concentration (mg/kg) assumed throughout the entire landfill. The COPCs for evaluation were all calculated at depth because the contaminated soil will be beneath a 2-ft layer of gravel. COPCs were evaluated at a conservative depth of six inches. If appropriate, this value was then compared to the background soil concentrations at the INEEL (Rood, Harris, and White 1995). If the values were below background concentrations they were eliminated from further consideration. COPCs were then compared to screening criteria. COPCs that were above screening criteria were brought forward to the next level of screening.

The maximum mass of each radiological COPC (totaled for all sites) was divided by the volume capacity of the ICDF landfill (318,000 m^3) to yield the mg/kg of radiological COPC through the entire landfill. This weight value was then converted to piC/g using published half-lives and atomic mass for each isotope.

The concentrations were compared to screening criteria or BDAC values. Radiological COPCs with concentrations above screening criteria were brought forward as potential concerns to the next level of screening.

To ensure that possible cumulative effects from multiple contaminants are accounted for, a total screening level quotient or hazard index will be calculated at each step of the process. The advantages of using this approach during the EBSL/BDAC screening are that it allows the summation of effects, the determination of relative risk from the contaminants under consideration, and the propagation of higher-risk contaminants through to more detailed risk assessment, while dropping those with low risk. For the initial screening step, a screening level hazard quotient (SLQ) was calculated. Calculation of the SLQ is the maximum concentration divided by the EBSL. The SLQs were then summed across the pathways by functional group and/or T/E species to calculate a total screening level quotient (TSLQ). A TSLQ greater than 1.0 for nonradionuclide COPCs and 0.1 for radionuclide COPCs would indicate that no risk is apparent.

All organic and inorganic COPCs were analyzed for their cumulative effect on receptors. A TSLQ evaluation was performed to ensure that organic COPCs contributing to accumulated risk were brought forward in the analysis (Tables 11 and 12 present the SLQ for avian and mammalian receptors as well as the COPCs percent contribution to risk). Based on evaluation of the percent contribution to the total SLQ, any COPC within 0.25 of an EBSL was brought to the next step (HQ analysis). Inorganic COPCs with concentrations below background concentrations were eliminated from further consideration. Those COPCs brought forward to HQ analysis are acetone, aroclor-1254, boron, copper, cyanide, fluoride, lead, mercury (inorganic), molybdenum, nitrate, pentachlorophenol, selenium, silver, strontium, sulfate, xylene, zinc, and zirconium.

All radiological COPCs were analyzed for their cumulative effect on receptors. A TSLQ evaluation was performed to ensure that radiological COPCs contributing to accumulated risk were considered (Table 13 presents the SLQs for internal and external as well as the COPC's percent contribution to risk). Any radiological COPC within 0.25 of an EBSL was brought to the next step (HQ analysis) due to multiple contamination. The following radiological contaminants were brought forward to assess their cumulative effects on receptors: Am-241, Ba-137m, Cs-137, Eu-152, Eu-154, Pu-238, Pu-239, Sr-90, Kr-85.

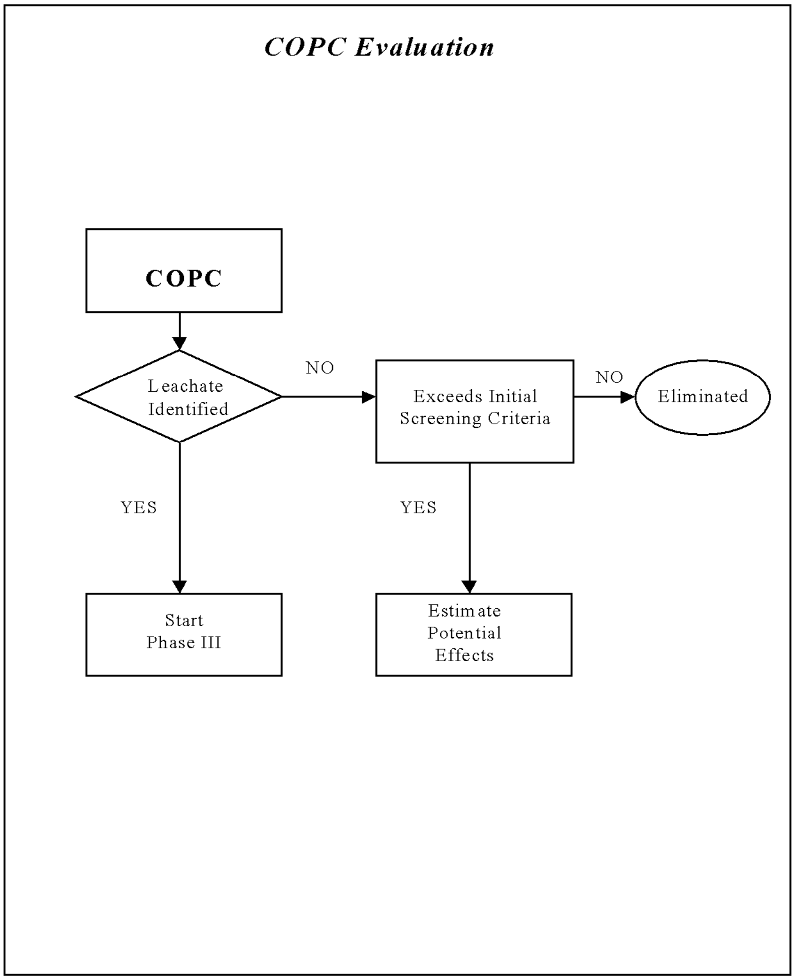

Figure 5. Evaluation process for COPCs identified as present in soil and leachate.

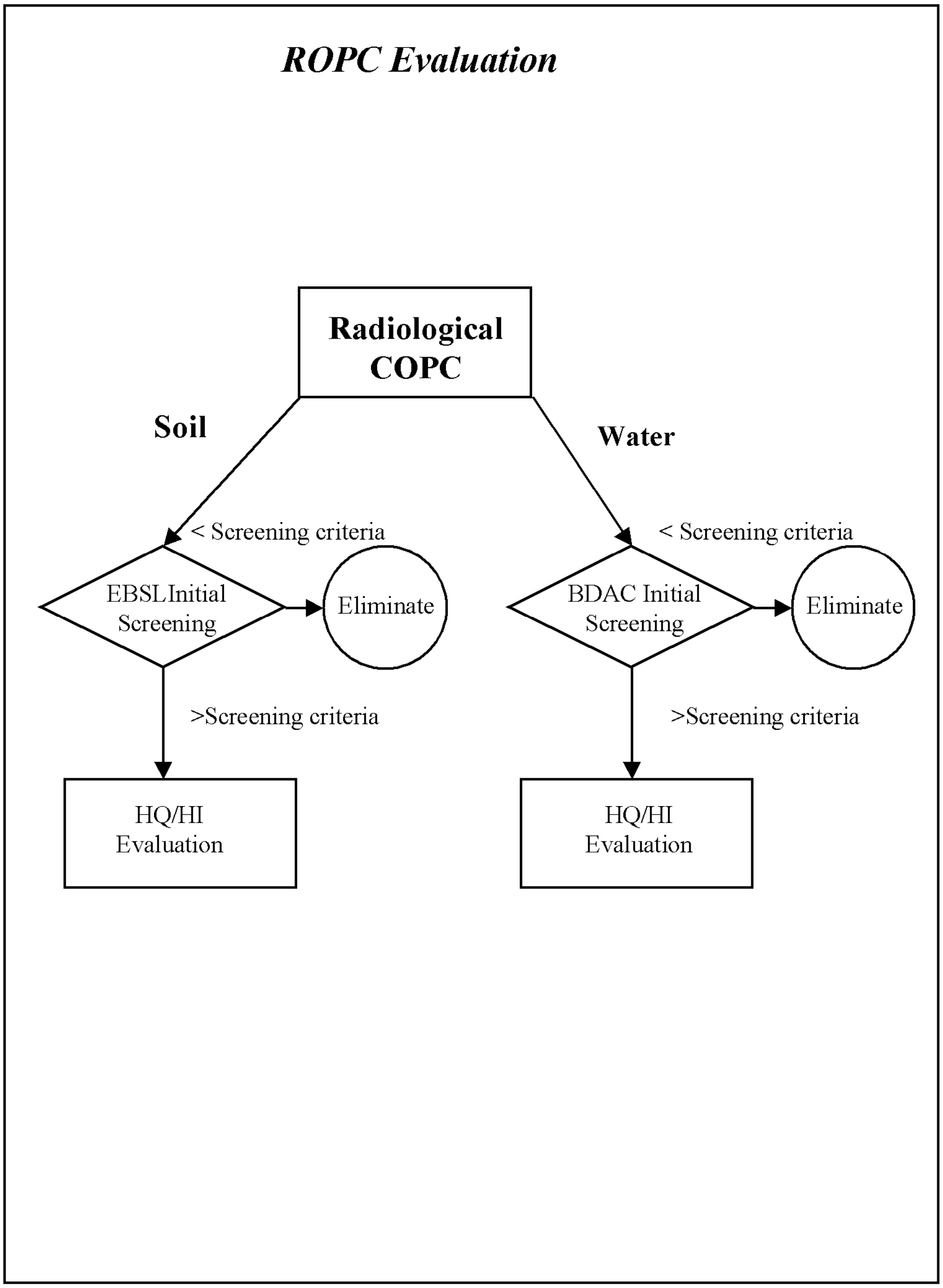

Figure 6. Evaluation process for radiological COPCs identified as present in soil and leachate.

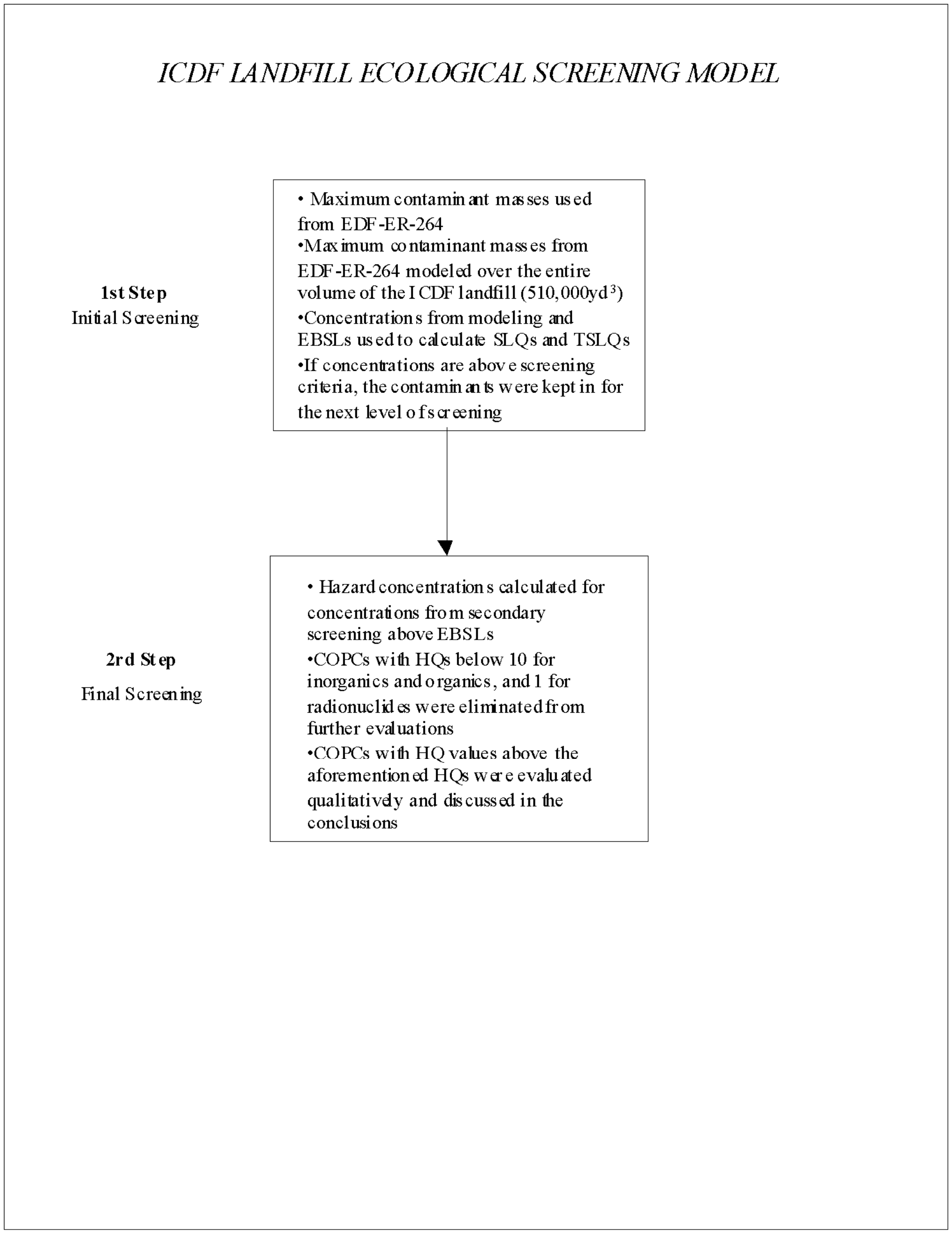

Figure 7. IDCF landfill ecological risk assessment soil screening process.

3.1.1.1 Initial Screening for Organic Contaminants in Soil. Table 11 presents the initial screening for organic contamiants in soil. Those COPCs brought forward to HQ analysis are acetone, aroclor-1254, pentachlorophenol, and xylene.

3.1.1.2 Initial Screening for Inorganic Contaminants in Soil. Table 12 presents the initial screening for inorganic contaminants in soil. Those COPCs brought forward to HQ analysis are boron, copper, cyanide, fluoride, lead, mercury (inorganic), molybdenum, nitrate, selenium, silver, strontium, sulfate, zinc, and zirconium.

3.1.1.3 Initial Screening for Radiological Contaminants in Soil. Table 13 presents the initial screening of **radiological** COPCs in soil. The following radiological contaminants were brought forward to assess their cumulative effects on receptors: Am-241, Ba-137m, Cs-137, Eu-152, Eu-154, Pu-238, Pu-239, Sr-90, Kr-85.

3.1.1.4 Initial Screening for Radiological Contaminants in Water. The DOE (headquarters) has recently developed frameworks, methods and guidance for demonstrating protection of the environment from the effects of ionizing radiation. This proposed standard is called A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE, in preparation). It is approved by EH-4 for interim use by DOE program and field elements in evaluating doses to biota. A graded approach for evaluating doses to biota was developed using an interdisciplinary team approach through a DOE-sponsored Biota Dose Assessment Committee. A three-phased process was provided: (1) defining the evaluation area and assembling radionuclide concentration data; (2) applying an easy-to-use general screening methodology that provides limiting radionuclide concentration values (Biota Concentration Guides, BCGs) for radionuclides in soil, sediment and water; and, if needed, (3) conducting site-specific analysis using site-representative parameters in place of default values, a kinetic/allometric modeling tool, or an actual site-specific biota dose assessment involving the collection of biota within an eco-risk framework. This technical standard provides dose evaluation methods that can be used to meet the requirements of DOE Orders 5400.1 and 5400.5.

The DOE standard provides a general screening that allows the concentrations of radionuclides in water, co-located sediments, and soils to be evaluated for both the aquatic and terrestrial system. For those radiological COPCs that have both leachate and soil concentration, this approach was used. It is well accepted that sediment and water contaminant concentrations will come to equilibrium within a system. For this analysis it is not appropriate to calculate a sediment concentration from the water since this will be the leachate concentration estimated over 15 years of operation. Therefore, for this assessment, the water concentration summed over all years of operation is considered conservative of the dose that receptors using the pond would receive. Generic Biotic Concentration Guides (BCGs) are used within each system. A sum of fractions approach is used in comparing radionuclide concentrations in environmental media with the BCGs contained in the standard lookup tables. When multiple radionuclides are present in multiple environmental media, the sum of fractions rule should be applied to account for all sources of exposure. Hence, the sum of the ratios of the concentration for each radionuclide to its corresponding BCG for each medium should then be summed across media, and the total sum of fractions should not exceed 1.0.

Table 11. Initial EBSL screening for organic contaminants for soil against the maximum contaminant concentration.

COPC	Maximum Contaminant Mass (kg) from EDF-ER-264	Maximum Concentration (mg/kg)	Minimum EBSL for Avian	Minimum EBSL for Mammalian	SLQs for Avian	SLQs for Mammalian	%Avian[a]	%Mammalian[a]	Plant Benchmark
1,1,1-Trichloroethane	7.40E+00	1.27E-02	NA	8.13E+02	NA	1.56E-05	NA	0.00%	NA
1,1,2,2-Tetrachloroethane	2.30E-02	3.94E-05	NA	1.67E+01	NA	2.36E-06	NA	0.00%	NA
1,2,4-Trichlorobenzene	5.40E+00	9.26E-03	NA	1.82E+00	NA	5.09E-03	NA	0.04%	NA
1,2-Dichloroethane	2.50E-03	4.29E-06	1.39E+00	1.11E+01	3.09E-06	3.86E-07	0.00%	0.00%	NA
1,3-Dichlorobenzene	5.40E+00	9.26E-03	NA	7.82E-02	NA	1.18E-01	NA	0.97%	NA
1,4-Dioxane	8.90E-03	1.53E-05	NA	1.58E-02	NA	9.68E-04	NA	0.01%	NA
2,4-Dimethylphenol	8.60E+00	1.47E-02	NA	3.75E+01	NA	3.92E-04	NA	0.00%	NA
2,4-Dinitrotoluene	5.40E+00	9.26E-03	NA	1.54E+00	NA	6.01E-03	NA	0.05%	NA
2,6-Dinitrotoluene	9.80E+00	1.68E-02	NA	2.18E+00	NA	7.71E-03	NA	0.06%	NA
2-Butanone	1.20E+01	2.06E-02	NA	3.83E+01	NA	5.38E-04	NA	0.00%	NA
2-Methylnaphthalene	2.40E+02	4.12E-01	NA	A	NA	NA	NA	NA	NA
4-Chloroaniline	1.90E+01	3.26E-02	NA	5.35E-01	NA	6.09E-02	NA	0.50%	NA
4-Methylphenol	1.80E+01	3.09E-02	NA	4.92E+00	NA	6.28E-03	NA	0.05%	NA
Acenaphthene	9.60E+01	1.65E-01	NA	4.74E+01	NA	3.48E-03	NA	0.03%	NA
Acetone	2.90E+02	4.97E-01	NA	5.53E-01	NA	8.99E-01	NA	7.36%	NA
Acetonitrile	8.90E-03	1.53E-05	NA	3.08E-01	NA	4.97E-05	NA	0.00%	NA
Acrylonitrile	4.30E-03	7.37E-06	NA	1.15E-02	NA	6.41E-04	NA	0.01%	NA
Anthracene	1.50E+02	2.57E-01	NA	1.35E+02	NA	1.90E-03	NA	0.02%	NA
Aroclor-1016	3.60E+00	6.17E-03	c	c	NA	NA	NA	NA	b
Aroclor-1254	6.10E+01	1.05E-01	1.66E-01	3.57E-01	0.63253	2.94E-01	100.00%	2.41%	40
Aroclor-1260	3.40E+02	5.83E-01	NA	8.02E+00	NA	7.27E-02	NA	0.60%	40
Aroclor-1268	2.90E+01	4.97E-02	c	c	NA	NA	NA	NA	b

Table 11. (continued).

COPC	Maximum Contaminant Mass (kg) from EDF-ER-264	Maximum Concentration (mg/kg)	Minimum EBSL for Avian	Minimum EBSL for Mammalian	SLQs for Avian	SLQs for Mammalian	%Avian[a]	%Mammalian[a]	Plant Benchmark
Benzene	2.90E+02	4.97E-01	NA	5.50E+00	NA	9.04E-02	NA	0.74%	NA
Benzo(a)anthracene	1.20E+02	2.06E-01	NA	3.02E+01	NA	6.82E-03	NA	0.06%	NA
Benzo(a)pyrene	5.00E+01	8.57E-02	NA	2.69E+00	NA	3.19E-02	NA	0.26%	NA
Benzo(b)fluoranthene	8.50E+01	1.46E-01	NA	B	NA	NA	NA	NA	NA
Benzo(g,h,i)perylene	5.40E+00	9.26E-03	NA	b	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	8.80E+00	1.51E-02	NA	b	NA	NA	NA	NA	NA
Butylbenzylphthalate	3.20E+01	5.49E-02	NA	1.43E+01	NA	3.84E-03	NA	0.03%	NA
Chrysene	1.30E+02	2.23E-01	NA	b	NA	NA	NA	NA	NA
Diethylphthalate	5.40E+00	9.26E-03	NA	1.53E+02	NA	6.05E-05	NA	0.00%	NA
Di-n-butylphthalate	1.10E+01	1.89E-02	NA	1.50E+01	NA	1.26E-03	NA	0.01%	200
Di-n-octylphthalate	1.20E+01	2.06E-02	NA	4.71E+01	NA	4.37E-04	NA	0.00%	NA
Ethylbenzene	3.70E+01	6.34E-02	NA	5.52E+01	NA	1.15E-03	NA	0.01%	NA
Fluoranthene	3.60E+02	6.17E-01	NA	3.38E+01	NA	1.83E-02	NA	0.15%	NA
Fluorene	8.70E+01	1.49E-01	NA	3.38E+01	NA	4.41E-03	NA	0.04%	NA
Indeno(1,2,3-cd)pyrene	5.40E+00	9.26E-03	NA	b	NA	NA	NA	NA	NA
Methylene Chloride	4.00E+01	6.86E-02	NA	1.00E+00	NA	6.86E-02	NA	0.56%	NA
Naphthalene	2.00E+02	3.43E-01	NA	1.43E+00	NA	2.40E-01	NA	1.97%	NA
Nitrobenzene	5.40E+00	9.26E-03	NA	1.96E+00	NA	4.72E-03	NA	0.04%	NA
Pentachlorophenol	2.60E+01	4.46E-02	NA	1.30E-01	NA	3.43E-01	NA	2.81%	NA
Phenanthrene	5.50E+02	9.43E-01	NA	1.35E+02	NA	6.99E-03	NA	0.06%	NA
Phenol	3.80E+01	6.52E-02	NA	8.23E+00	NA	7.92E-03	NA	0.06%	70
Pyrene	1.20E+02	2.06E-01	NA	4.20E+01	NA	4.90E-03	NA	0.04%	NA
Tetrachloroethene	4.60E+00	7.89E-03	NA	3.33E+00	NA	2.37E-03	NA	0.02%	NA

Table 11. (continued).

COPC	Maximum Contaminant Mass (kg) from EDF-ER-264	Maximum Concentration (mg/kg)	Minimum EBSL for Avian	Minimum EBSL for Mammalian	SLQs for Avian	SLQs for Mammalian	%Avian[a]	%Mammalian[a]	Plant Benchmark
Toluene	4.70E+02	8.06E-01	NA	6.04E+01	NA	1.33E-02	NA	0.11%	NA
Tributylphosphate	1.70E+02	2.91E-01	NA	3.99E+01	NA	7.29E-03	NA	0.06%	NA
Trichloroethene	3.40E+01	5.83E-02	NA	1.74E+01	NA	3.35E-03	NA	0.03%	NA
Xylene (ortho)	1.80E+00	3.09E-03	NA	2.78E-01	NA	1.11E-02	NA	0.09%	NA
Xylene (total)	1.60E+03	2.74E+00	NA	2.78E-01	NA	9.86E+00	NA	80.75%	NA
Total SLQ					0.632533	12.20609	100.00%	100.00%	

a. % values for avian or mammalian are the SLQ for each COPC divided by the total SLQ

b. Values for benzo(a)pyrene used.

c. Values for Aroclor-1254 used.

Note: Highlighting of a value indicates that COPC concentration is above the EBSL.

Table 12. Initial EBSL screening for inorganic contaminants in soil against the maximum contaminant concentrations from Table 2.

COPC	Maximum Contaminant Mass (kg) from EDF-ER-264	Maximum Concentration (mg/kg)	Background Soil Concentrations (mg/kg)	Below Background Soil Concentrations	Minimum EBSL for Avian	Minimum EBSL for Mammalian	Plant Benchmark	SLQ for Avian	SLQ for Mammalian	%Avian[a]	%Mammalian[a]
Aluminum	3.40E+06	5.83E+03	1.60E+04	Yes	1.55E+02	8.50E+00	50	3.76E+01	6.86E+02	8.07%	28.36%
Antimony	2.80E+03	4.80E+00	4.80E+00	Yes	0.00E+00	1.35E+00	5	NA	3.56E+00	NA	0.15%
Arsenic	2.70E+03	4.63E+00	5.80E+00	Yes	1.28E+00	8.44E-01	10	3.62E+00	5.49E+00	0.78%	0.23%
Barium	8.50E+04	1.46E+02	3.00E+02	Yes	0.00E+00	1.10E+01	500	NA	1.33E+01	NA	0.55%
Beryllium	1.40E+02	2.40E-01	1.80E+00	Yes	0.00E+00	7.14E-01	10	NA	3.36E-01	NA	0.01%
Boron	8.70E+04	1.49E+02	NA	No	9.25E+00	2.56E+00	0.5	1.61E+01	5.82E+01	3.45%	2.41%
Cadmium[b]	1.70E+03	2.91E+00	2.20E+00	No	3.83E-02	2.36E-03	3	7.60E+01	1.23E+03	16.29%	50.98%
Calcium	9.70E+06	1.66E+04	2.40E+04	Yes	NA	NA	NA	NA	NA	NA	NA
Chromium III	1.90E+04	3.26E+01	3.30E+01	Yes	2.82E+00	8.11E+02	1	1.16E+01	4.02E-02	2.48%	0.00%
Cobalt	2.90E+03	4.97E+00	1.10E+01	Yes	4.35E-01	4.27E-01	NA	1.14E+01	1.16E+01	2.45%	0.48%
Copper	1.40E+04	2.40E+01	2.20E+01	No	9.54E+00	2.11E+00	100	2.52E+00	1.14E+01	0.54%	0.47%
Cyanide	1.60E+02	2.74E-01	NA	No	1.43E-01	5.84E+00	NA	1.92E+00	4.69E-02	0.41%	0.00%
Fluoride	1.80E+03	3.09E+00	NA	No	2.69E+00	3.40E+01	NA	1.15E+00	9.09E-02	0.25%	0.00%
Iron	4.90E+06	8.40E+03	2.40E+04	Yes	NA	NA	NA	NA	NA	NA	NA
Lead	2.70E+04	4.63E+01	1.70E+01	No	9.94E-01	8.76E+00	50	4.66E+01	5.29E+00	9.99%	0.22%
Magnesium	2.10E+06	3.60E+03	1.20E+04	Yes	1.86E+01	1.05E+01	500	1.94E+02	3.43E+02	41.50%	14.18%
Manganese	9.80E+04	1.68E+02	4.90E+02	Yes	NA	NA	NA	NA	NA	NA	NA
Mercury (inorganic)	4.50E+03	7.72E+00	NA	No	4.18E+00	3.57E-01	0.3	1.85E+00	2.16E+01	0.40%	0.89%
Molybdenum	4.80E+03	8.23E+00	NA	No	0.00E+00	1.07E+01	2	NA	7.69E-01	NA	0.03%
Nickel	9.30E+03	1.59E+01	3.50E+01	Yes	6.83E+01	6.17E+01	30	2.33E-01	2.58E-01	0.05%	0.01%
Nitrate	1.90E+03	3.26E+00	NA	No	1.84E+01	5.52E+01	NA	1.77E-01	5.91E-02	0.04%	0.00%
Potassium	5.30E+05	9.09E+02	4.30E+03	Yes	NA	NA	NA	NA	NA	NA	NA
Selenium	4.00E+02	6.86E-01	2.20E-01	No	1.72E-01	4.22E-01	1	3.99E+00	1.63E+00	0.86%	0.07%
Silver	4.70E+03	8.06E+00	NA	No	3.02E+01	3.67E+01	2	2.67E-01	2.20E-01	0.06%	0.01%
Sodium	1.00E+05	1.71E+02	3.20E+02	Yes	NA	NA	NA	NA	NA	NA	NA
Strontium	8.60E+03	1.47E+01	NA	No	0.00E+00	5.91E+00	NA	NA	2.49E+00	NA	0.10%

Table 12. (continued).

COPC	Maximum Contaminant Mass (kg) from EDF-ER-264	Maximum Concentration (mg/kg)	Background Soil Concentrations (mg/kg)	Below Background Soil Concentrations	Minimum EBSL for Avian	Minimum EBSL for Mammalian	Plant Benchmark	SLQ for Avian	SLQ for Mammalian	%Avian[a]	%Mammalian[a]
Sulfate	9.70E+03	1.66E+01	NA	No	1.78E+01	1.72E+01	NA	9.33E-01	9.65E-01	0.20%	0.04%
Thallium	1.80E+02	3.09E-01	4.30E-01	Yes	1.01E-01	1.30E-01	1	3.06E+00	2.38E+00	0.66%	0.10%
Vanadium	1.00E+04	1.71E+01	4.50E+01	Yes	7.87E+00	1.49E+00	200	2.17E+00	1.15E+01	0.47%	0.47%
Zinc	9.90E+04	1.70E+02	1.50E+02	No	3.29E+00	3.18E+01	50	5.17E+01	5.35E+00	11.08%	0.22%
Zirconium	3.30E+04	5.66E+01	NA	No	0.00E+00	3.23E+02	NA	NA	1.75E-01	NA	0.01%
Total SLQ								4.66E+02	2.42E+03	100.00%	100.00%

a. % values for avian or mammalian are the SLQ for each COPC divided by the total SLQ

b. Cadmium was eliminated from the analysis although it is a major contributor to the risk. EPA (2000) found that levels of 29 mg/kg for plants and 110 mg/kg for soil invertebrates are acceptable. Cadmium availability is highly dependent on pH and chemical speciation. It is not anticipated to be a problem under our site-situation.

Note: Highlighting of a value indicates that the COPC concentration is above the EBSL.

Table 13. Initial EBSL screening for radiological contaminants in soil using the maximum concentration from Table 3.

COPC	Maximum Concentration from EDF-ER-264 pCi/g	External Dose EBSL	Internal Dose EBSL	SLQ for External	SLQ for Internal	%External[b]	%Internal[b]
Ac-225	4.11E-08	2.92E+05	1.70E+01	1.41E-13	2.42E-09	0.00%	0.00%
Ac-227	1.66E-05	2.40E+07	2.04E+05	6.92E-13	8.14E-11	0.00%	0.00%
Ac-228	1.23E-10	3.29E+03	3.10E+03	3.74E-14	3.97E-14	0.00%	0.00%
Ag-108	3.08E-09	1.82E+03	1.78E+03	1.69E-12	1.73E-12	0.00%	0.00%
Ag-108m	6.51E-01	1.82E+03	4.01E+03	3.58E-04	1.62E-04	0.00%	0.00%
Ag-109m	3.94E-12	9.01E+05	1.99E+06	4.37E-18	1.98E-18	0.00%	0.00%
Ag-110	4.28E-11	1.06E+03	9.37E+02	4.04E-14	4.57E-14	0.00%	0.00%
Ag-110m	4.45E-09	1.08E+03	2.20E+03	4.12E-12	2.02E-12	0.00%	0.00%
Am-241	1.88E+01	1.32E+05	1.78E+01	1.42E-04	1.06E+00	0.00%	4.34%
Am-242	3.60E-05	1.66E+05	5.32E+02	2.17E-10	6.77E-08	0.00%	0.00%
Am-243	2.74E-04	5.70E+04	1.85E+01	4.81E-09	1.48E-05	0.00%	0.00%
At-217	4.11E-08	1.24E+07	1.38E+01	3.31E-15	2.98E-09	0.00%	0.00%
Ba-137m	1.88E+04	4.95E+03[a]	1.09E+04[a]	3.80E+00	1.72E+00	43.40%	7.08%
Be-10	9.25E-07	NA	9.63E+03	NA	9.61E-11	NA	0.00%
Bi-210	8.90E-07	NA	5.01E+03	NA	1.78E-10	NA	0.00%
Bi-212	4.45E-04	1.23E+03	6.66E+02	3.62E-07	6.68E-07	0.00%	0.00%
Bi-214	4.62E-06	1.99E+03	3.83E+03	2.32E-09	1.21E-09	0.00%	0.00%
C-14	3.77E-05	NA	3.94E+04	NA	9.57E-10	NA	0.00%
Cd-109	3.94E-12	1.98E+05	4.36E+05	1.99E-17	9.04E-18	0.00%	0.00%
Ce-141	1.46E-71	4.22E+04	1.18E+04	3.46E-76	1.24E-75	0.00%	0.00%
Ce-144	1.47E-03	1.87E+05	2.27E+04	7.86E-09	6.48E-08	0.00%	0.00%
Cf-252	1.88E-20	1.45E+08	1.64E+01	1.30E-28	1.15E-21	0.00%	0.00%
Cm-242	4.45E-17	1.24E+08	1.60E+01	3.59E-25	2.78E-18	0.00%	0.00%
Cm-244	1.46E-03	2.30E+08	1.68E+01	6.35E-12	8.69E-05	0.00%	0.00%
Cm-248	1.59E-16	3.35E+08	2.10E+01	4.75E-25	7.57E-18	0.00%	0.00%
Co-57	2.91E-03	2.45E+04	5.40E+04	1.19E-07	5.39E-08	0.00%	0.00%
Co-58	4.79E-17	3.66E+03	7.17E+03	1.31E-20	6.68E-21	0.00%	0.00%
Co-60	1.58E+02	1.18E+03	1.12E+03	1.34E-01	1.41E-01	1.53%	0.58%
Cr-51	1.88E-54	9.39E+04	2.07E+05	2.00E-59	9.08E-60	0.00%	0.00%
Cs-134	9.08E+00	1.90E+03	3.14E+03	4.78E-03	2.89E-03	0.05%	0.01%
Cs-137	2.05E+04	4.95E+03	5.58E+03	4.14E+00	3.67E+00	47.33%	15.08%
Eu-152	7.88E+02	2.27E+03	2.18E+03	3.47E-01	3.61E-01	3.97%	1.48%
Eu-154	6.68E+02	2.48E+03	3.31E+03	2.69E-01	2.02E-01	3.08%	0.83%
Eu-155	1.44E+02	5.95E+04	3.25E+04	2.42E-03	4.43E-03	0.03%	0.02%
Fe-59	3.60E-35	2.48E+03	4.12E+03	1.45E-38	8.74E-39	0.00%	0.00%
Fr-221	4.11E-08	8.98E+04	1.53E+01	4.58E-13	2.69E-09	0.00%	0.00%
Fr-223	2.23E-07	5.85E+04	5.47E+03	3.81E-12	4.08E-11	0.00%	0.00%
Gd-152	2.23E-14	NA	4.53E+01	NA	4.92E-16	NA	0.00%
Gd-153	1.63E-11	5.32E+04	1.17E+05	3.06E-16	1.39E-16	0.00%	0.00%
H-3	3.94E+01	NA	3.43E+05	NA	1.15E-04	NA	0.00%
Hf-181	6.34E-37	5.69E+03	7.12E+03	1.11E-40	8.90E-41	0.00%	0.00%
I-129	1.04E+00	9.88E+05	4.76E+04	1.05E-06	2.18E-05	0.00%	0.00%
Kr-85	9.42E+02	1.88E+04	3.70E+03	5.01E-02	2.55E-01	0.57%	1.05%

Table 13. (continued).

COPC	Maximum Concentration from EDF-ER-264 pCi/g	External Dose EBSL	Internal Dose EBSL	SLQ for External	SLQ for Internal	%External[b]	%Internal[b]
La-140	2.23E-105	1.43E+03	1.67E+03	1.56E-108	1.34E-108	0.00%	0.00%
Mn-54	1.56E-08	3.53E+03	7.79E+03	4.42E-12	2.00E-12	0.00%	0.00%
Nb-93m	1.10E-02	1.51E+06	3.33E+06	7.28E-09	3.30E-09	0.00%	0.00%
Nb-94	7.19E-06	1.87E+03	3.14E+03	3.84E-09	2.29E-09	0.00%	0.00%
Nb-95	3.94E-33	3.56E+03	6.69E+03	1.11E-36	5.89E-37	0.00%	0.00%
Np-237	5.14E-01	1.46E+05	1.94E+01	3.52E-06	2.65E-02	0.00%	0.11%
Np-239	2.74E-04	1.71E+04	1.17E+04	1.60E-08	2.34E-08	0.00%	0.00%
Np-240m	2.05E-11	8.83E+03	2.83E+03	2.32E-15	7.24E-15	0.00%	0.00%
Pa-231	5.65E-05	9.89E+04	2.37E+01	5.71E-10	2.38E-06	0.00%	0.00%
Pa-233	3.60E-02	1.90E+04	1.70E+04	1.89E-06	2.12E-06	0.00%	0.00%
Pa-234m	1.39E-03	2.58E+05	2.37E+03	5.39E-09	5.86E-07	0.00%	0.00%
Pb-210	8.90E-07	1.57E+06	2.74E+05	5.67E-13	3.25E-12	0.00%	0.00%
Pb-212	4.45E-04	2.53E+04	1.45E+04	1.76E-08	3.07E-08	0.00%	0.00%
Pb-214	4.62E-06	1.29E+04	6.78E+03	3.58E-10	6.81E-10	0.00%	0.00%
Pm-147	3.08E+02	NA	3.15E+04	NA	9.78E-03	NA	0.04%
Po-210	8.22E-07	NA	1.84E+01	NA	4.47E-08	NA	0.00%
Po-212	2.74E-04	NA	1.11E+01	NA	2.47E-05	NA	0.00%
Po-214	4.62E-06	NA	1.27E+01	NA	3.64E-07	NA	0.00%
Po-216	4.45E-04	NA	1.44E+01	NA	3.09E-05	NA	0.00%
Po-218	4.62E-06	NA	1.62E+01	NA	2.85E-07	NA	0.00%
Pr-144	1.44E-03	2.86E+05	1.61E+03	5.03E-09	8.94E-07	0.00%	0.00%
Pu-238	1.88E+02	1.13E+05	1.78E+01	1.66E-03	1.06E+01	0.02%	43.36%
Pu-239	5.48E+00	2.66E+06	1.89E+01	2.06E-06	2.90E-01	0.00%	1.19%
Pu-240	1.22E+00	1.94E+06	1.89E+01	6.29E-07	6.46E-02	0.00%	0.27%
Pu-241	5.14E+01	NA	3.73E+05	NA	1.38E-04	NA	0.00%
Pu-242	1.88E-04	2.34E+06	2.00E+01	8.03E-11	9.40E-06	0.00%	0.00%
Pu-244	2.05E-11	2.70E+06	2.12E+01	7.59E-18	9.67E-13	0.00%	0.00%
Ra-224	4.45E-04	3.11E+05	2.56E+01	1.43E-09	1.74E-05	0.00%	0.00%
Ra-225	4.11E-08	2.54E+05	2.00E+04	1.62E-13	2.06E-12	0.00%	0.00%
Ra-226	3.77E-01	4.83E+05	2.04E+01	7.81E-07	1.85E-02	0.00%	0.08%
Ra-228	1.23E-10	NA	1.97E+05	NA	6.24E-16	NA	0.00%
Rh-103m	2.23E-58	1.71E+06	3.78E+06	1.30E-64	5.90E-65	0.00%	0.00%
Rh-106	9.25E-03	1.62E+04	1.33E+03	5.71E-07	6.95E-06	0.00%	0.00%
Rn-220	4.45E-04	5.36E+06	1.55E+01	8.30E-11	2.87E-05	0.00%	0.00%
Rn-222	4.97E-06	7.20E+07	1.78E+01	6.90E-14	2.79E-07	0.00%	0.00%
Ru-103	1.63E-29	6.38E+03	9.23E+03	2.55E-33	1.77E-33	0.00%	0.00%
Ru-106	9.93E-03	NA	1.94E+05	NA	5.12E-08	NA	0.00%
Sb-124	1.68E-40	1.65E+03	1.38E+03	1.02E-43	1.22E-43	0.00%	0.00%
Sb-125	7.53E+00	7.12E+03	6.02E+03	1.06E-03	1.25E-03	0.01%	0.01%
Sc-46	2.23E-20	1.47E+03	2.73E+03	1.52E-23	8.17E-24	0.00%	0.00%
Sm-147	3.25E-06	NA	4.34E+01	NA	7.49E-08	NA	0.00%
Sn-119m	1.20E-07	7.65E+05	1.69E+06	1.57E-13	7.10E-14	0.00%	0.00%
Sr-89	4.79E-44	1.62E+07	3.34E+03	2.96E-51	1.43E-47	0.00%	0.00%
Sr-90	1.88E+04	NA	3.34E+03	NA	5.63E+00	NA	23.11%
Tc-99	4.62E+00	2.36E+04	1.60E+04	1.96E-04	2.89E-04	0.00%	0.00%

Table 13. (continued).

COPC	Maximum Concentration from EDF-ER-264 pCi/g	External Dose EBSL	Internal Dose EBSL	SLQ for External	SLQ for Internal	%External[b]	%Internal[b]
Te-125m	1.88E+00	8.42E+04	1.86E+05	2.23E-05	1.01E-05	0.00%	0.00%
Th-228	2.74E-02	1.51E+06	1.81E+01	1.81E-08	1.51E-03	0.00%	0.01%
Th-229	4.11E-08	7.15E+04	3.60E+01	5.75E-13	1.14E-09	0.00%	0.00%
Th-230	1.40E-01	7.76E+06	2.09E+01	1.80E-08	6.70E-03	0.00%	0.03%
Th-231	1.30E-01	1.63E+05	2.33E+04	7.98E-07	5.58E-06	0.00%	0.00%
Th-232	1.27E-01	1.81E+07	2.43E+01	7.02E-09	5.23E-03	0.00%	0.02%
Th-234	1.39E-03	3.66E+05	4.16E+04	3.80E-09	3.34E-08	0.00%	0.00%
Tm-170	5.14E-26	1.07E+06	6.17E+03	4.80E-32	8.33E-30	0.00%	0.00%
U-232	4.28E-04	1.66E+06	1.54E+01	2.58E-10	2.78E-05	0.00%	0.00%
U-233	2.05E-05	1.02E+07	2.03E+01	2.01E-12	1.01E-06	0.00%	0.00%
U-234	4.97E+00	2.01E+06	2.05E+01	2.47E-06	2.42E-01	0.00%	1.00%
U-235	8.90E-02	2.16E+04	2.27E+01	4.12E-06	3.92E-03	0.00%	0.02%
U-236	1.64E-01	2.15E+06	2.17E+01	7.63E-08	7.56E-03	0.00%	0.03%
U-238	1.58E+00	2.44E+06	2.32E+01	6.48E-07	6.81E-02	0.00%	0.28%
U-240	2.05E-11	4.39E+05	1.54E+04	4.67E-17	1.33E-15	0.00%	0.00%
Xe-131m	2.23E-112	1.47E+05	3.23E+05	1.52E-117	6.90E-118	0.00%	0.00%
Y-90	1.88E+04	4.68E+03[a]	1.74E+03[a]	NA	NA	NA	NA
Zn-65	2.23E-09	5.21E+03	1.13E+04	4.28E-13	1.97E-13	0.00%	0.00%
Zr-93	7.02E-01	NA	9.95E+04	NA	7.06E-06	NA	0.00%
Zr-95	2.40E-25	3.69E+03	5.49E+03	6.50E-29	4.37E-29	0.00%	0.00%
Total SLQ				8.75E+00	2.44E+01	100.00%	100.00%

a. Eliminated from consideration due to the extremely short half life (Miller, R. E., BBWI, conversation with S. W. Perry, BBWI, August 15, 2001, "Radiological information.").

b. % values for avian or mammalian are the SLQ for each COPC divided by the total SLQ

Note: Highlighting of a value indicates that the COPC concentration is above the EBSL.

Table 14 presents the results of the analysis for radionuclides identified in the leachate, sediment, and soil. None of the three radionuclides detected in both the leachate and soil exceeds the standards criteria. However, for future monitoring of this facility, it is important to note that the use of concentration data from co-located surface water and sediment samples is preferred and will result in a less conservative, more realistic evaluation.

Table 14. Results of the analysis for radionuclides identified in the leachate, sediment, and soil.

	Leachate Concentration (pCi/L)	BCG[a] (water) (pCi/L)	Ratio (water)	Sediment Concentration (pCi/g)	BCG (sediment) (pCi/g)	Ratio (sediment)
Aquatic System						
I-129	3.4E+03	2.7E+04	0.126	NA	NA	NA
Tc-99	6.75E+03	5.40E+05	0.013	NA	NA	NA
U-238	8.64E+00	2.16E+02	0.040	NA	NA	NA
Sum of ratios			0.179			NA

	Leachate Concentration (pCi/L)	BCG (water) (pCi/L)	Ratio (water)	Soil Concentration (pCi/g)	BCG (soil) (pCi/g)	Ratio (soil)
Terrestrial System						
I-129	3.4E+03	5.4E+06	0.001	1.04E+00	6.E+03	0.000
Tc-99	6.75E+03	3.42E+06	0.000	9.62E+00	4.E+03	0.002
U-238	8.64E+00	5.4E+05	0.000	1.58E+00	2.E+03	0.001
Sum of ratios			0.001			0.003

a. BCG = Biotic Concentration Guides.

3.2 Hazard Quotient Analysis

The final level of screening was an analysis of hazard quotients (HQs) and hazard indices (HIs). Risk was estimated by the screening of modeled concentrations of contaminants planned for disposal at the ICDF to TRVs. Average concentrations used in this SLERA were from the Design Inventory (EDF-ER-264) and the CWID report, as discussed previously. Concentrations were calculated based upon an agreed method (Section 1.1.1) of assuming the contaminant mass evenly distributed throughout the entire volume.

If the dose from the contaminant does not exceed its TRV (i.e., if the HQ is less than 10 for nonradiological contaminants and 1.0 for radiological contaminants), adverse effects to ecological receptors from exposure to that contaminant are not expected. Hence, the HQ is an indicator of potential risk. HQs are calculated using the following equation:

$$HQ = \frac{Dose}{TRV} \tag{26}$$

where

HQ = hazard quotient (unitless)

$Dose$ = dose from all media (mg/kg/day or pCi/g/day)

TRV = toxicity reference value (mg/kg/day or pCi/g/day).

If information was not available to derive a TRV, then an HQ could not be developed for that particular contaminant and species combination.

For each group of contaminants by receptor the HQs will be summed to produce a total HI. This will then used to evaluate the cumulative risk to receptors from COPCs concentrations modeled to be present using similar criteria as the HQ analysis. It is important to consider additive effects from all COPCs for each receptor or receptor group. A HI greater than the target value would imply a possible effect to a receptor from all contaminants combined.

The advantages of using a HI approach is that it allows the summation of effects and the determination of relative risk from a suite of contaminants under consideration. The disadvantages of this approach is that it assumes that effects from contaminants are additive. It is more likely that some effects will be additive and still other effects may be synergistic (either positively or negatively). Little is known about synergism of contaminant effects. Strictly speaking, summing may only be appropriate when the contaminants have equivalent effects. Effects from the nonradioactive metals and organics are expected to cause systemic toxicity (although some are also carcinogens), while the effect associated with exposure to ionizing radiation is typically cancer. This may also be true of other classes of contaminants. The effects of the uncertainty inherent in the HI should be discussed.

For multiple contaminants, especially radionuclides, it is recommended to reduce the target HQ to 1/n, where n is the number of contaminants or concern. This approach would be more conservative than strictly adding the HQs but it still does not address the possible synergistic behavior of a group of contaminants in a given receptor.

It is important to discuss the HIs in the WAG SLERA results, but it will be difficult to actually determine their meaning. The correct usage of any quotient method is highly dependent on professional judgement, particularly in instances when the quotient approaches the risk target.

All organic and inorganic COPCs were analyzed for their cumulative effect on receptors. A HI (hazard index) evaluation was performed to ensure that inorganic and organic COPCs contributing to accumulated risk were considered. Table B-1 in Appendix B presents the results of HQ analysis for the inorganic and organic COPCs contributing to accumulated risk.

All radiological COPCs were analyzed for their cumulative effect on receptors. A HI evaluation was performed to insure that radiological COPCs contributing to accumulated risk were considered. Table B-2 in Appendix B presents the results of HQ analysis for the aforementioned radiological COPCs contributing to accumulated risk.

The contaminants retained for evaluation in the ecological risk assessment (ERA) from the soil at the ICDF landfill include: acetone, aroclor-1254, boron, copper, cyanide, fluoride, lead, mercury (inorganic), molybdenum, nitrate, pentachlorophenol, selenium, silver, strontium, sulfate, xylene, zinc, zirconium, Am-241, Ba-137m, Cs-137, Eu-152, Eu-154, Pu-238, Pu-239, Sr-90, Kr-85. Ten additional contaminants (as leachates) were evaluated for ecological risk from water concentrations in the evaporation ponds. These contaminants may have been eliminated in the initial soil screening, but have been retained in the ERA for further evaluation because of possible ecological risk from concentrations in the water from the evaporation ponds. These include arsenic, boron, calcium, chlorine, magnesium, potassium, selenium, sulfate, vanadium, and zinc. Hazard quotients (HQs) could not be calculated for calcium or chlorine because of the lack of toxicity data to develop toxicity reference values. Calcium is an essential nutrient and is only considered toxic in excessive amounts. The Leachate/Contaminant Reduction Time Study (EDF-ER-274) included all constituents existing in solution as anions (this includes chlorine). These elements were then modeled using geochemical modeling to develop concentrations of the element in the leachate. EDF-ER-274 states that the modeled leachate is a brackish to saline water dominated by sodium and sulfate with a pH of 8.2. Chlorine is a strong oxidizer that will react rapidly with inorganic compounds in water. Given this environment and the reactivity it is assumed that the chlorine is existing as sodium chloride (or another dissolved salt) in the leachate. Given that the leachate will be diluted by make up water and based on studies presented in the Mineral Tolerance of Domestic Animals (NAS 1980) (indicating that very high levels of sodium chloride can be tolerated) chlorine will not be further evaluated. These contaminants (calcium and chlorine) pose a low risk to ecological receptors and will no longer be evaluated. The exposure dose for both boron and selenium will include soil ingestion and water ingestion. By evaluating both pathways together, the calculated risk would be the most conservative.

3.2.1 Final Screening for Inorganic and Organic Contaminants

Only contaminants with HIQs greater than 10 will be retained for further evaluation in the SLERA. These contaminants and HIs are presented in the following discussion. Contaminants with HQs less than or equal to 10 are eliminated from the SLERA because they pose a low risk to ecological receptors and no longer need to be evaluated. Risks from these contaminants to reptiles, amphibians, and invertebrates could not be evaluated because of the lack of toxicity data to develop TRVs.

The hazard quotient calculation does not take into account the 2 ft of gravel to be placed over the contaminated area, limiting the exposure to ecological receptors modeled in the risk assessment approach. As mentioned in Section 1.1.1, the modeled contaminant concentrations are also considered very conservative. Therefore, the risk calculation is highly conservative. Receptor groups with HIs above 10 and the contributing inorganic and organic contaminats are discussed below. Those groups with HIs below 10 were eliminated from further evaluation. Those COPCs adding to cumulative risk were included in the discussion. The COPC adding the most to cumulative risk and its percent of the total HI is indicated in parenthesis.

- Avian herbivores (AV122): Zinc was the major contributor to cumulative risk (49%); boron, cyanide, lead, mercury also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 38.7.

- Avian insectivores (AV210A): Zinc was the major contributor to cumulative risk (44%); lead, mercury, selenium also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 12.3.

- Avian insectivores (AV221): Zinc was the major contributor to cumulative risk (44%); lead, mercury, selenium also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 13.8.

- Avian insectivores (AV222): Zinc was the major contributor to cumulative risk (42%); lead, mercury, selenium also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 21.0.

- Avian insectivores (AV222A): Zinc was the major contributor to cumulative risk (42%); lead, mercury, selenium also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 13.7.

- Mammalian herbivore (M122): Boron was the major contributor to cumulative risk (40%); acetone, copper, mercury, sulfate, xylene, zinc also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 37.6.

- Mammalian herbivore (M122A): Boron was the major contributor to cumulative risk (39%); acetone, copper, mercury, sulfate, xylene, zinc also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 34.2.

- Pygmy rabbit: Boron was the major contributor to cumulative risk (40%); copper, mercury, xylene also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this receptor is 13.9.

- Mammalian herbivore (M123): Boron was the major contributor to cumulative risk (40%); copper, mercury, sulfate, xylene, zinc also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 21.3.

- Townsend's western big-eared bat: Copper was the major contributor to cumulative risk (34%); mercury also had HQs above 1.0 and was a significant contributor to cumulative risk. The total HI for this receptor is 10.2.

- Small-footed myotis: Copper was the major contributor to cumulative risk (34%); mercury, selenium, sulfate, zinc also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this receptor is 14.6.

- Long-eared myotis: Copper was the major contributor to cumulative risk (34%); mercury, selenium, sulfate, zinc also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this receptor is 12.6.

- Mammalian insectivores (M222): Copper was the major contributor to cumulative risk (33%); mercury, selenium, sulfate, zinc also had HQs above 1.0 and were significant contributors to cumulative risk. The total HI for this group is 13.6.

3.2.2 Final Screening for Radiological Contaminants

Only radionuclide contaminants with HIs greater than 1 will be retained for further evaluation in the SLERA. These contaminants and HQs are presented in the following discussion. Contaminants with HQs less than or equal to 1 are eliminated from the SLERA because they pose a low risk to ecological receptors and no longer need to be evaluated.

The hazard quotient calculation does not take into account the 2 ft of gravel to be placed over the contaminated area, limiting the exposure pathway to ecological receptors. Therefore, calculated HQs for this site are not expected to be as high and cause the risk evaluation to be overly conservative. The HQs for external and internal exposure to radionuclides at the ICDF Complex are discussed below. Receptor groups with HIs above 1.0 and the contributing radiological contaminats are discussed below. Those groups with HIs below 1.0 were eliminated from further evaluation. Those COPCs adding to cumulative risk were included in the discussion. The COPC adding the most to cumulative risk and its percent of the total HI is indicated in parenthesis.

3.2.3 External Exposure to Radionuclides

- Amphibians (A232): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Avian herbivores (AV122): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Avian insectivores (AV210A): Ba-137m is the major contributor to cumulative risk (80%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 1.3.

- Avian insectivores (AV221): Ba-137m is the major contributor to cumulative risk (80%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 1.3.

- Avian insectivores (AV222): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Avian insectivores (AV222A): Ba-137m is the major contributor to cumulative risk (80%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 1.3.

- Avian carnivores (AV322): Ba-137m is the major contributor to cumulative risk (79%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 1.2.

- Loggerhead shrike: Ba-137m is the major contributor to cumulative risk (80%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this receptor is 1.3.

- Avian omnivores (AV422): Ba-137m is the major contributor to cumulative risk (78%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 1.0.

- Mammalian herbivores (M122): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Mammalian herbivores (M122A): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Pygmy rabbit: Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this receptor is 2.1.

- Mammalian herbivores (M123): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Mammalian insectivores (M210): Ba-137m is the major contributor to cumulative risk (80%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 1.0.

- Townsend's western big-eared bat: Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this receptor is 2.1.

- Small-footed myotis: Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this receptor is 2.1.

- Long-eared myotis: Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this receptor is 2.1.

- Mammalian insectivores (M222): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Mammalian omnivore (M422): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Reptilian insectivores (R222): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

- Sagebrush lizard: Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this receptor is 2.1.

- Reptilian carnivores (R322): Ba-137m is the major contributor to cumulative risk (76%); Cs-137 is also a significant contributor to cumulative risk. The total HI for this group is 2.1.

3.2.4 Internal Exposure to Radionuclides

- Amphibians (A232): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Avian herbivores (AV121): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 5.7.

- Avian herbivores (AV122): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Avian insectivores (AV210): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 9.5.

- Black tern: Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 3.7.

- Avian insectivores (AV210A): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 14.9.

- Avian insectivores (AV221): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 14.9.

- Avian insectivores (AV222): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Avian insectivores (AV222A): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 14.9.

- Avian carnivores (AV322): Cs-137 is the major contributor to cumulative risk (37%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 12.9.

- Loggerhead shrike: Cs-137 is the major contributor to cumulative risk (37%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 14.2.

- Avian carnivores (AV322A): Cs-137 is the major contributor to cumulative risk (37%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 2.9.

- Burrowing owl: Cs-137 is the major contributor to cumulative risk (37%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 2.9.

- Avian omnivores (AV422): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 11.2.

- Mammalian herbivores (M121): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 2.8.

- Mammalian herbivores (M122): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Mammalian herbivores (M122A): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Pygmy rabbit: Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 22.9.

- Mammalian herbivores (M123): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Mammalian insectivores (M210): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 11.5.

- Mammalian insectivores (M210A): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 5.7.

- Townsend's western big-eared bat: Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 22.9.

- Small-footed myotis: Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 22.9.

- Long-eared myotis: Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 22.9.

- Mammalian insectivores (M222): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Mammalian carnivores (M322): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 9.4.

- Mammalian omnivore (M422): Cs-137 is the major contributor to cumulative risk (37%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 21.8.

- Mammalian omnivore (M422A): Cs-137 is the major contributor to cumulative risk (37%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 7.8.

- Reptilian insectivores (R222): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

- Sagebrush lizard: Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this receptor is 22.9.

- Reptilian carnivores (R322): Cs-137 is the major contributor to cumulative risk (35%); Ba-137m, Eu-152, Eu-154, Pu-238, Sr-90, and K-85 all have HQs above 0.1 and are considered significant contributors to cumulative risk. The total HI for this group is 22.9.

4. DEVELOPMENT OF ACCEPTABLE LEACHATE CONCENTRATIONS

Due to the uncertainty associated with the masses and the subsequent modeling of the leachate concentration, acceptable leachate concentrations (ALCs) for use at the ICDF were developed for those COPCs identified in the Leachate/Contaminant Reduction Time Study (EDF-ER-274). Radiological COPCs should be evaluated using the proposed standard A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE, in preparation). It is approved by EH-4 for interim use by DOE program and field elements in evaluating doses to biota. This technical standard provides dose evaluation methods that can be used to meet the requirements of DOE Orders 5400.1 and 5400.5.

The leachate is considered the major pathway of exposure to ecological receptors since the soil exposure will be limited by the 2-ft clean fill layer maintained during facility operations and the biobarrier that will be in place with the facility is completed. These ALCs can then be used to calculate the acceptable mass using the approach documented in EDF-ER-274.

The approach is based on EPA (1999) and is considered less conservative since it more completely models the food web than the EBSL and HQ analysis documented in VanHorn, Hampton, and Morris (1995) that was primarily used in this analysis. It is presented in Appendix A. In this approach, species were selected as receptors were chosen to evaluate the pathways presenting the most likely route of exposure from potential contaminants at the ICDF leach pond. Both terrestrial and aquatic receptors were selected since the leach pond will be used by waterfowl. However aquatic organisms, such as fish and other benthic organisms, were not assessed since this facility is not considered a natural water body. After the ICDF mission (estimated 15 years) is accomplished the pond will be eliminated as a source of drinking water for those species present at the INEEL. The deer mouse, mule deer, coyote, Townsend's western big-eared bat, mourning dove, sage grouse, red-tailed hawk, and bald eagle were selected as terrestrial receptors. The mallard duck and spotted sandpiper are included as aquatic receptors for assessment at the ICDF leach pond. These species although modeled as having a limited use of the facility are the risk drivers due to the exposure from aquatic sources.

They are included based on the results of the following observational study. Cieminski (1993) studied wildlife use of wastewater ponds at the INEEL. In general, she found that ponds which are large, nutrient-rich, heavily vegetated, and have a low shoreline slope are predicted to have higher wildlife use than ponds which are small, nutrient-poor, and have bare, steep shorelines (Ceminski 1993). She goes on to suggest that sanitary waste ponds, or other ponds which pose negligible health risks to wildlife could be maintained in the former state and toxic ponds in the latter.

Cieminski (1993) evaluated many of the ponds at the INEEL, however, specifically, she evaluated the INTEC percolation ponds. These ponds are most likely to be similar to the ICDF leach pond under construction. Most use of these ponds was by migrating waterfowl, and with one exception (green-winged teal in 1991), no birds are known to nest at the site. The large open ponds were attractive to migrating waterfowl, but the bare shorelines were not attractive to passerines. More species use occurred at these ponds when the water level was low, creating vegetated gravel bars. This is unlikely to occur with the ICDF pond design. The sewage ponds at INTEC also provide a more attractive alternative pond for use, particularly for shorebirds. Raptors were found to visit the ponds less frequently than any other avian group.

Another study found that the residence time of ducks on wastewater ponds was less than 48 hours (Browers and Flake 1983). Due to this information the exposure period for the mallard, spotted sandpiper and bald eagle were significantly reduce. It was assumed that these species would feed for a week totally from the foodweb present at the ICDF pond for 1 week. Therefore the area use factor was reduced to 0.02.

The suspected contaminants were taken from the proposed inventory of contaminants to be disposed of in the landfill. The suspected leachate contaminants included; arsenic, boron, calcium, chlorine, magnesium, phosphorus, potassium, selenium, sulfur, vanadium, and zinc. Calcium, magnesium, and potassium were eliminated from the list of COPCs because these chemicals are essential nutrients and are not considered toxic unless present in extremely high concentrations (10X background values). Chlorine was also eliminated as a COPC because chlorine is a strong oxidizer and will react rapidly with inorganic compounds. The presence of light will also accelerate the dissipation of chlorine in water (Vulcan chemicals). Therefore, chlorine is not likely to remain in the pond for a long period of time.

For the remaining COPCs, ALCs were back calculated from the hazard quotient (of 1.0) to present the allowable leachate concentrations that maybe present in the leach pond. These calculated ALCs are presented in Table 15 (taken from Table A-1) along with the ambient water concentrations and sediment quality concentrations. Results of this analysis are presented in Appendix A.

Table 15. Acceptable leachate concentrations for use at the ICDF.

COPC	ALC (mg/L)	Modeled Leachate Concentrations (mg/L)	Ambient Water Criteria (ug/L)	Sediment Quality Criteria (ppb dry weight)
Arsenic	6	1.53	340	5,900
Boron	—[a]	40.7	—	—
Calcium	—[b]	4.86	—	—
Chlorine	—[c]	16.6	19	—
Magnesium	—[b]	0.25	—	—
Phosphorus	—[d]	6.8	—	—
Potassium	—[b]	0.089	—	—
Selenium	0.07	0.073	5.0 (13-186)	290
Sulfur	—[c, d]	373	—	—
Vanadium	3	3.48	—	50,000
Zinc	8	0.031	120	123,100

a. Boron has no toxicity for aquatic and no AWQC.

b. Toxicity reference values are not available to establish an ALC for calcium, magnesium, or potassium. However, these COPCs are essential nutrients, and are not considered toxic expected under extremely high concentrations (10X background).

c. A soil-water partition coefficient (Kd) value was not available for chlorine or sulfur so an ALC could not be calculated.

d. Toxicity reference values were not available for establishing an ALCs for phosphorus or sulfur.

NOTE: — = no information available.

5. DISCUSSION OF UNCERTAINTY

5.1 Organic Uncertainty

Organic compounds expected to be present in the waste disposed in the ICDF landfill were identified from Table B2 in the Design Inventory (EDF-ER-264). This table presents a list of organic compounds that have been detected or estimated from the release sites destined for disposal in the ICDF landfill. Concentrations and contaminant masses are based on process knowledge from release sites and are substituted for other sites that had similar processes. Actual concentrations and masses in these sites are most likely overestimated or underestimated causing a more conservative or less conservative evaluation of these compounds. An attempt was made to overestimate due to the purposes of the Design Inventory (EDF-ER-264).

5.2 Inorganic Uncertainty

Inorganic compounds expected to be present in the waste disposed in the ICDF landfill were identified from Table C2 in the Design Inventory (EDF-ER-264). This table presents a list of inorganic compounds that have been detected or estimated from the release sites destined for disposal in the ICDF landfill. Concentrations and contaminant masses are based on process knowledge from release sites and are substituted for other sites that had similar processes. Actual concentrations and masses in these sites are most likely overestimated or underestimated, causing a more conservative or less conservative evaluation of these compounds. An attempt was made to overestimate due to the purposes of the Design Inventory (EDF-ER-264).

5.3 Radionuclide Uncertainty

Analytical data on the following radionuclides were detected at one or more release sites: Ag-108m, Am-241, Ce-144, Co-57, Co-60, Cs-134, Cs-137, Eu-152, Eu-154, Eu-155, I-129, K-40, Np-237, Pu-238, Pu-239, Pu-239/240, Ra-226, Ru-106, Sb-125, Sr-90, Tc-99, Th-228, Th-230, Th-232, H-3, U-234, U-235, U-238.

The remaining radionuclides were calculated using a scaling factor based on Cs-137. This was done based on the likelihood that other radionuclides found in typical reactor operations could be present. Whether or not the radionuclides are actually present and at what amounts is uncertain. EBSL information is present for a portion of the radionuclides but not all of them. Those radionuclides that did not have EBSL information were assessed using the same methodology as the other radionuclides and evaluated qualitatively. K-40 was the only radionuclide detected at the release sites that did not have EBSL information to screen against. It was calculated to be 1.37 pCi/g. K-40 makes up 0.0117% of all potassium occurring in nature. At 1.37 pCi/g, K-40 is probably the naturally occurring amount for this area.[d] Actual concentrations and masses in these sites are most likely overestimated or underestimated, causing a more conservative or less conservative evaluation of these compounds. An attempt was made to overestimate due to the purposes of the Design Inventory (EDF-ER-264).

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d. Miller, R. E., BBWI, conversation with S. W. Perry, BBWI, August 15, 2001, "Radiological information."

5.4 Hazard Quotients Uncertainty

An HQ greater than the target value indicates that exposure to a given contaminant; however, the level of concern associated with exposure may not increase linearly as HQ values exceed the target value. Therefore, the HQ values cannot be used to represent a probability or a percentage because an HQ of 10 does not necessarily indicate that adverse effects are 10 times more likely to occur than an HQ of 1. It is only possible to infer that the greater the HQ, the greater the concern about potential adverse effects to ecological receptors. The HQ equation is unable to account for subsurface contamination and thus surface contamination is treated the same when, in fact, the depth of the contamination makes a difference. Secondly the ICDF will be a highly disturbed area during the 10 years it takes the area to be filled. The habitat will be unfavorable to the species considered. Finally, the use of a biobarrier, once the volume is filled, will increase the depth of the contamination that the HQ equation will not calculate.

The hazard quotient calculation based on the exposure modeled does not take into account the 2 ft of gravel to be placed over the contaminated area. This gravel should limit the exposure pathway to ecological receptors. Also the estimated concentrations and masses of the contaminants are very conservative. Therefore, the risk evaluation performed in this analysis is likely to be highly conservative.

The ICDF SLERA, by definition, is a conservative approach to assess the potential for risk to ecological receptors from contaminants during interim disposal of waste identified in the Design Inventory (EDF-ER-264). The SLERA incorporates levels of uncertainty that could either overestimate or underestimate the actual risk to these receptors. To compensate for potential uncertainties, the SLERA incorporates various factors that are designed to be conservative rather than result in a conclusion of no indication of risk when actual risk may exist. Regardless, uncertainties exist that could affect the estimation of true risk associated with the assessment area. These are summarized in Table 16.

Principal sources of uncertainty lie within the development of an exposure assessment and toxicity assessment. Uncertainties inherent in the exposure assessment are associated with estimation of receptor IRs, estimation of site usage, and estimation of PUFs and BAFs. Additional uncertainties are associated with the depiction of site characteristics, the determination of the nature and extent of contamination, and the derivation of TRVs. All of these uncertainties are likely to influence risk estimates. This is not an estimate of the risk to ecological receptors when the facility is finally closed without the biobarrier (greater than 10 ft).

The risk drivers tend to be from radionuclide contamination. This is at least in part explained by the determination of toxicity values. For radionuclides, the TRVs are based on effects to populations, while for nonradionuclides, the TRVs are based on effects to individuals. As such, the nonradionuclide toxicity data is in this sense more conservative than the radionuclide toxicity data.

In relation to extrapolations between individuals and populations, it is difficult to accurately predict ecological effects of toxic substances because of the complexity of the ecosystem. Most toxicity information comes from laboratory studies of single contaminant impacts on single species. Hence, there is a great deal of uncertainty in extrapolating controlled laboratory results to complex field situations and from one species to another. Single contaminant studies cannot predict the interactions of multiple contaminants with each other and with the ecosystem. Additionally, interactions of organisms with the ecosystem are complex and not easily predicted.

Few data are available for the invertebrate populations at the INEEL. Invertebrates are important links in dietary exposure for wildlife. There is insufficient ecological and toxicological data to adequately characterize the contaminant effects in the invertebrate component of the ecosystem. Such uncertainty will propagate into some of the other endpoint compartments, in particular those representing mammalian, avian, and reptilian insectivores.

The area used in the HQ calculations was very conservative. A cross section was calculated that encompassed the top layer of the pit when completely filled with the contaminated soil (5.35 hectares). The pit was modeled assuming the receptors would have access to the entire pit when in fact it will be gradually filled over time and the actual area that a receptor would be exposed to would be less than the value used in the HQ calculations.

Table 16. Sources and effects of uncertainties in the ecological risk assessment.

Uncertainty Factor	Effect of Uncertainty (level of magnitude)	Comment
Estimation of IRs (soil and food)	May overestimate or underestimate risk (moderate)	Few intake ingestion estimates used for terrestrial receptors are based on data in the scientific literature (preferably site-specific when available). Food IRs are calculated by using allometric equations available in the literature (Nagy 1987). Soil ingestion values are generally taken from Beyer, Conner, and Gerould (1994) as shown in Table 9. Soil ingestion may be a major pathway of exposure. Assumptions made in extrapolating soil ingestion data from species to species may introduce significant uncertainty into the assessment.
Estimation of bioaccumulation and plant uptake factors and use of default values in calculating PUFs	May overestimate risk and the magnitude of error cannot be quantified (high)	Few BAFs or PUFs are available in the literature that are both contaminant- and receptor-specific. In the absence of more specific information, PUFs and BAFs for metals were obtained from Baes et al. (1984) and other literature sources and for organics from Travis and Arms (1988).
Estimation of toxicity reference values	May overestimate (high) or underestimate (moderate) risk	To compensate for potential uncertainties in the exposure assessment, various adjustment factors are incorporated to extrapolate toxicity from the test organism to other species.
Elimination of COPCs based on the lack of EBSL information	May underestimate (low) risk	COPC inventories were very conservatively modeled. The lack of EBSL information may underestimate the risk to receptors but not significantly.
Use of functional grouping	May overestimate (high)	Functional groups were designed as an assessment tool that would ensure that the SLERA would address all species potentially present at the facility. A hypothetical species is developed using input values to the exposure assessment that represents the greatest exposure of the combined functional group members.

Table 16. (continued).

Uncertainty Factor	Effect of Uncertainty (level of magnitude)	Comment
Use of estimated concentrations and quantities	May overestimate (high) or underestimate (very low)	Contaminant masses in the Design Inventory (EDF-ER-264) were very conservative and were based on facility design.
Use of simplistic modeling of exposure	May overestimate (high)	Without the ability to set the parameters for contamination at depth, the risk posed to an individual or receptor group can be overestimated.

There are a number of T/E or sensitive species that could occur in the ICDF assessment area. In some cases, they are known to exist in close proximity to INTEC facilities. The lack of information concerning the presence or absence of T/E and/or sensitive species in the vicinity of INEEL facilities and at the INEEL in general has been previously identified as an acceptable data gap.

Ecotoxicological data is recognized as one of the major uncertainties in SLERA. The TRVs are updated as new information is available. This is an ongoing effort that will continue throughout the SLERA process at the INEEL.

6. ICDF SLERA SUMMARY AND RESULTS

A screening of modeled concentrations of contaminants planned for disposal at the ICDF based on EBSLs and HQs was performed. Screening methods were very conservative, as were the modeled inventories. As discussed, the concentrations used in this SLERA were from the Design Inventory (EDF-ER-264) and/or the CWID (DOE-ID 2000). The Design Inventory contaminant masses were very conservatively modeled and primarily developed to support design of the facility. As discussed in the uncertainty section, some estimated masses were included in the Design Inventory to provide a conservative overestimate. The Design Inventory (EDF-ER-264) states that it should not be used to approximate actual site conditions. However, it does provide an initial approximation of the wastes that may be disposed of in the ICDF landfill and used to model the leachate concentrations anticipated in the evaporation pond. These values were used in this risk assessment. Actual concentrations that ecological receptors will be exposed to, may be lower (or higher, although that is less likely) than the calculated or modeled concentrations used for this assessment.

The approach used to assess exposure to the landfill was also conservative. It was assumed that ecological receptors would be exposed to the concentrations of contaminants at the landfill as if the 2-ft clean fill layer did not exist. Also, the other controls and activities at the facility will reduce the amount of exposure to most ecological receptors at the landfill. The presence of water in the evaporation pond and other related structures (buildings etc.), may however, encourage use by selected species. For example, bats and other birds may feed on insects from the pond and higher trophic level avian species (hawks) may use power poles. As discussed, the ingestion of water was evaluated in conjunction with the exposure evaluated at the landfill. For all contaminants, the maximum concentration anticipated to be in the surface water was evaluated. It is expected that this will overestimate the exposure because COPCs and radiological COPCs in the pond should go to equilibrium with the sediment reducing the concentrations. Since the pond is not a natural body of water, no evaluation was conducted for such groups of species as benthic organisms or fish. As discussed in Section 4.0, the mallard and spotted sandpiper however, were assessed during the development of ALCs. This is documented in Appendix A. From this analysis, it was determined that the modeled leachacte concentrations for all the COPCs should be acceptable to these two species feeding on the pond for a week. The pond should be maintained to ensure that conditions do not encourage more than transient use by these species.

Using this approach, the following conclusions and recommendations can be made:

- Exposure to ecological receptors at the ICDF could be more definitely evaluated by
    - Using sensitivity studies for individual species exhibiting high HQ values.
    - Further evaluating estimated concentrations.

The ICDF Complex appears to have some potential to provide unacceptable exposure to ecological receptors. It is recommended that

- The 2-ft clean fill layer be maintained during facility operations to prevent exposure of the contaminated soil to ecological receptors.

- The pond should be built with bare, steep shorelines and conditions be maintained to limit nutrient enrichment and vegetation.

- Continual monitoring and evaluation during the facility operation be implemented to ensure that the modeling assumptions are correct and that necessary preventive measures are implemented to reduce exposure to ecological receptors. The selected COPCs/radiological COPCs should be taken from the results of the evaluation.

The ecological risk characterization indicates that boron concentrations in landfill soil could potentially reach concentration levels of concern but ecological risk is not anticipated since soil exposure will be limited by a 2-ft clean fill layer maintained during facility operations and a biobarrier will be in place when the facility is completed. The ecological risk characterization indicates that combined exposure to arsenic in both the landfill soil and the evaporation ponds could potentially be of concern but ecological risk is not anticipated since soil exposure will be limited by a 2-ft clean fill layer maintained during facility operations and a biobarrier will be in place when the facility is completed. The risk characterization indicates that sulfate and vanadium concentrations in the evaporation ponds could potentially reach concentration levels of concern to ecological receptors.

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